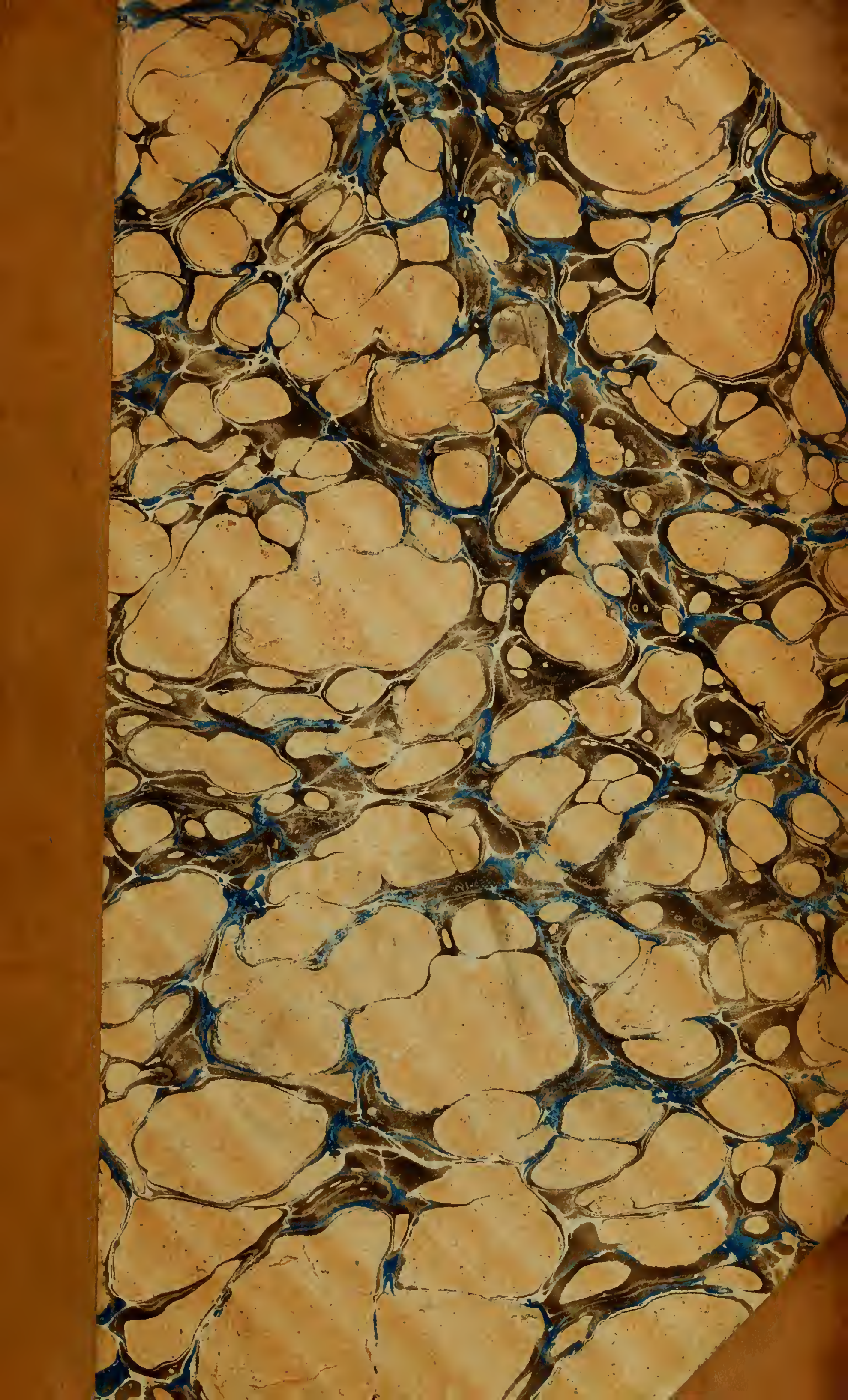

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EDITORIAL.

ITEMS AND NOVELTIES.

Machine for Testing the Value of Lubricants.—We give herewith an engraving of a machine for testing the value of lubricants by determining their power of reducing friction, resisting pressure, sustaining high temperatures, and cooling heated journals. The machine was invented by Professor R. H. Thurston, of the Stevens Institute of Technology, Hoboken, N. J., and the particular form shown in the illustration was designed by Mr. J. A. Henderson, a student in that institution.

The machine is intended to give the co-efficient of friction, pressure on bearing, and temperature of journal boxes at any time, and the readings are proposed to be taken at short intervals throughout the test.

The machine consists of a shaft, A, running in two bearings, B B, and driven by a pulley, C. The shaft is supported by a standard, D D, carried on the base, E E. At the outer end of the shaft is a journal, F, of either steel or selected iron; suspended from this journal, and clamping it by means of boxes, G G, is an arm, H H, carrying an adjustable weight, I, which may be changed for one of different size, or adjusted on the arm, as is found requisite.

The pressure under which the oil is to be tested is obtained by setting up the boxes, G G, by means of the screw K acting on the nut L, on which nut the spring J rests. The *pressure per square inch* is read off from the scale N N, which is traversed by an index, M, attached to the spring J. The friction causes the arm H H to swing out from the vertical position, the *moment of friction* being indicated by the index on the arm O, which traverses the graduated arc P P. The *co-efficient of friction* is obtained by dividing the reading on the scale cut on the arc P P, by a second set of empirical divisors laid off on the scale N N. The temperature is indicated at all times by a thermometer, Q Q, set in the upper brass.

In using the machine, a small and determinate quantity of the oil to be tested is placed on the journal F, and the pressure being adjusted by the screw K to that at which the oil is desired to run under test, the machine is started at a speed which will give the desired relative velocity of rubbing surfaces. Observations are made at short intervals, and recorded, until the test is closed by rapid heating, as shown by the thermometer, and excessive increase of friction, as indicated by the arm H H swinging up against its chocks. Competing oils are similarly tried, and the records afford a perfect means of comparison.

Thus, sewing-machine builders desire oil of long endurance and small frictional resistance and viscosity; on locomotives an oil that will bear high pressure for the greatest length of time without heating is the most desirable, even although not as limpid and of as slight frictional resistance. The relative power of resisting high temperatures without decomposition is another important point which may be tested.

Any lubricant may be tested, whether mineral, vegetable or animal oil, tallow or mixture like axle grease.

The only precautions necessary are not to allow the temperature to run so high as to injure the thermometer or the journal surface, and to measure accurately the quantity of oil used.

The form shown in the cut is that proposed for general use, but for extremely heavy pressures another form has been designed, in which the pressure on the journal is obtained by a clamp composed of a fixed arm and a spring, the spring being set up by a hand-wheel turning a nut in the end of the fixed arm. In this form of the machine, the moment of friction is measured by the compression of the spring. The essential feature of both forms is the combination in one machine of apparatus for making simultaneous dynamometrical and thermometrical tests of the lubricant.

Fig. 1

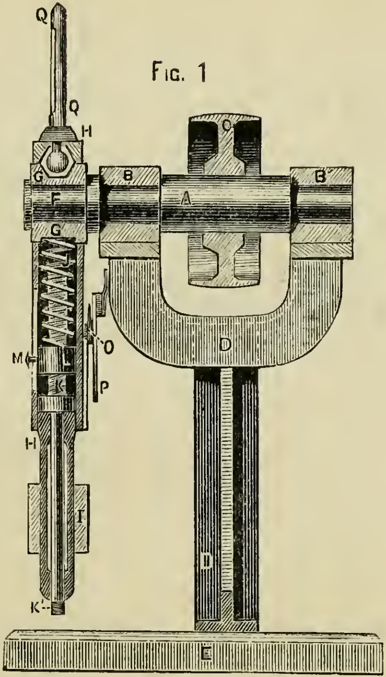
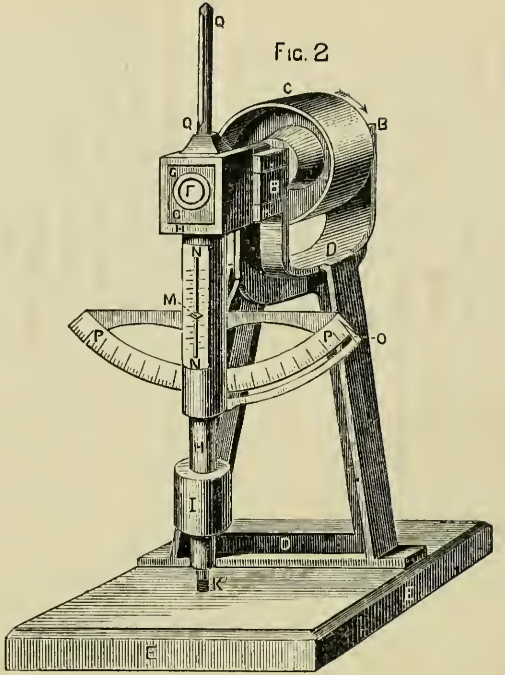


Fig. 2



MACHINE FOR TESTING THE VALUE OF LUBRICANTS.

The machine is patented by Professor Thurston, but the patentee announces that master mechanics can obtain permission to construct and use it on application to him. He will also furnish applicants with the necessary dimensions for the machines and with the numbers to be attached to them.*

Ingenious Engineering.—The *Chronique de l'Industrie* records a very ingenious piece of engineering, which is worthy of placing on record. During the construction of the bridge at Kuilenborg, Holland, one of the principal traverses, some 465 feet in length, was placed about one inch too far on the piles. This error, upon discovery, was rectified in the following manner:

The expansion of the mass of metal was ·0394 inches per Fahrenheit degree. At the locality of the work the difference between the temperature of the air by day and by night was 25° Fahr. In the morning the too far advanced end of the traverse was securely bolted down, when during the day the heat of the sun expanded the metal so that the free end advanced ·985 of an inch; then at night the other extremity was fastened down, and the contraction caused an equivalent movement of this end. By several operations of this kind the traverse was brought into proper position.

Consumption of Timber.—But few people are aware of the fearful drain which the railroads make upon the timber resources of the country, and a proper appreciation of this fact might lead speedily to the substitution of some cheap and practical material for the wooden tie now so universally employed.

The estimate is made upon good authority that the number of railroad ties at present in use is 150,000,000, and as young timber is mainly employed, a cut of 200 ties to the acre is above, rather than under, the average, and it has therefore required the product of 750,000 acres of well timbered land to furnish this supply.

As railroad ties have a life of about five years, about 30,000,000 ties are required annually for repairs—a supply which demands annually the product of 150,000 acres.

The manufacture of rolling stock requires annually the product of 350,000 acres more, from which data it appears that the railroads are depleting the woodland of the country at the rate of 500,000 acres per year—a demand which is also rapidly on the increase.

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* Railroad Gazette, May 17, 1873.

Growth of American Iron Industry.—The following table, from the compilation of the American Iron and Steel Association, exhibits in very concise form the growth of the home production, importation and consumption of rails in the United States from 1849 to 1872, inclusive, together with the growth of the American railway system during the same period.

YEAR.	Total rails made in the U. S.—Tons of 2000 lbs.	Total rails imported.——Tons of 2000 lbs.	Total consumption of iron and steel rails.	Miles of Railroad built in the U. S. in each year.
1849	24,318	69,163	93,481	1,369
1850	44,083	159,080	203,163	1,656
1851	50,603	226,350	276,953	1,961
1852	62,478	294,750	357,228	1,926
1853	87,864	358,794	446,658	2,452
1854	108,016	359,439	447,455	1,360
1855	138,674	153,019	291,693	1,654
1856	180,018	186,594	366,612	3,643
1857	161,918	215,166	377,084	2,491
1858	163,712	90,894	254,606	2,460
1859	195,454	83,958	279,412	1,821
1860	2050,38	146,610	351,648	1,846
1861	187,818	89,388	277,206	621
1862	213,912	10,186	224,098	864
1863	275,768	20,506	296,274	1,050
1864	385,369	142,457	447,826	738
1865	356,292	63,327	419,619	1,277
1866	430,778	117,878	548,656	1,832
1867	462,108	184,840	646,948	2,227
1868	506,714	300,160	806,874	3,033
1869	593,586	336,500	930,086	4,977
1870	620,000	472,403	1,092,403	6,145
1871	775,733	566,202	1,341,935	7,453
1872	941,992	530,850	1,471,842	6,043

A Japanese Suspension Bridge.—The statement is made that Mr. T. J. Waters, the surveyor general of the Japanese government, has lately completed the first suspension bridge in Japan. It is constructed over a ravine, filled with water, which separates the Mikado's palace from the pleasure garden, and is intended solely for the use of the Imperial household and attendants. According to the account of the structure, published in the Japan Weekly Mail, it appears to be 234 feet long, 17 feet wide, and 60 feet above the water. It is supported by two red brick columns, 64 feet high from the foundation, and the cables are of galvanized iron. The hand-rails are of thin wire rope, and, with the entire structure, are handsomely ornamented. The anchors are buried 23 feet deep, and the bridge has been tested with a rolling load of 20 tons.

American Rails.—The "Bulletin of the American Iron and Steel Association" lately contained some interesting statistics relative to the production of rails in the United States, from which it appears that the total number of net tons of rail reported for the year 1872 amounted to 941,992.

The production of each State, as well as the arranged table for comparing the same with that of 1871, is herewith submitted:

STATE.	1872.	1871.
Pennsylvania,	419,529	335,624
Ohio,	121.923	75,782
Illinois,	106,916	91,178
New York,	82,457	87,022
Wisconsin,	37,284	28,774
Massachusetts,	29,242	28,864
Maryland,	26,472	44,941
Indiana,	23,893	12,778
W. Virginia,	20,100	5,000
Missouri,	15,500	8,200
Mississippi,	14,620	9,667
Maine,	14,058	13,383
Michigan,	9,883	14,000
New Jersey,	9,185	6,700
Georgia,	6,930	7,840
Kentucky,	4,000	6,000
	941,992	775,733

The Woolwich Steam Hammer.*—The Woolwich workmen have lately been getting into place the great plate upon which is to rest the anvil block of the new thirty-five ton steam hammer. This plate weighs of itself one hundred and three tons, and had to be cast, of necessity, in an open mould. The surface which is to receive the anvil block lay, therefore, downward; and when, after many weeks, the colossal casting grew cool, it was needful to turn the huge mass completely over. On April 17th, an army of sturdy smiths undertook this task with hydraulic jacks, and a combination of the strongest tackle. Before night they had lifted the monstrous lump of solid metal, twenty-two feet square, and since then they have laid it in its bed, upon the rock-like structure of cement and piles made to receive it. The anvil block to be mounted on the huge plate, will weigh only a trifle short of 200 tons; and the steam-hammer which will strike upon it, is made of thirty-five tons of metal. The whole weight of metal in the hammer is about 500 tons.

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* Eng. and Mining Journal.

Coal in Russia.—Referring to this subject, one of our exchanges* states that an important advantage which Russia possesses, to which, however, it appears the inhabitants are not yet sufficiently alive, is the existence within their borders of an abundance of mineral fuel. As yet, however, notwithstanding the fine field for the development of the production of coal in Russia, scarcely any steps have been taken in this direction.

One magnificent deposit of unusually fine black gas coal is mentioned as especially valuable, occurring near the River Kama. It is stated to be thick near the surface, easily worked, and easily transported to the river side, but at present lying unutilized for want of proper enterprise.

Brown coal exists, according to our authority, in the central districts, large deposits of anthracite in the south, and immense beds in the basin of the Donetz, all of which await only the enterprise which shall dig it from its bed, and utilize it in the manufacture of its companion world-civilizer—iron.

English Railroad Statistics.—The very reliable compilation of the Board of Trade for 1871, shows that at the close of that year there were in the United Kingdom 15,376 miles of railroad, 123 miles having been constructed during the year. The average cost per mile had been £35,943 or about $180,000 gold. These roads earned an average of £3,063 or $15,300 per mile, of which earnings 44 per cent. was from passenger traffic and 56 per cent. from freight, and the average working expenses were about 48·4 per cent of the gross receipts. The average income earned on the capital invested was 4·43 per cent.

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* Iron.

The Incrustation of Boilers.—One of the papers read before the Master Mechanics' Association, which lately met in Baltimore, was the report of the committee on the operation and management of locomotive boilers, including the purification of water. The report, amongst several other recommendations, suggests for locomotives the remedy of employing rain water. The committee make a calculation to show that the collection and storage of rain water is practicable. In Missouri, for example, the annual rainfall is forty-one (41) inches. A reservoir covering one acre, and having a depth of sixteen to eighteen feet, with a roof or collecting surface of four acres, would receive 4,573,810 gallons of water per year. On a section of 100 miles of railroad, five of these reservoirs, located at intervals of twenty miles, would receive annually 22,869,000 gallons. A locomotive that does an average year's work (31,200 miles), consumes about 1,039,500 gallons of water, so that if the tonnage over the section necessitates the use of twenty engines, the five reservoirs would contain more than enough to supply them. The committee expressed the opinion that in the course of time, the saving in repairs to boilers would repay the amount expended in the construction of such reservoirs. The estimate being based upon the statement that the annual cost of repairs to a locomotive, made necessary by the use of impure water, is about $750.

Government Aid to Science.—It is gratifying to be able to notice that the Government has wisely responded to the urgent solicitations of engineers and the engineering press throughout the country in appropriating $100,000 for the purpose of continuing the experimental investigations upon steam boiler explosions, commenced by the Franklin Institute in 1835, and very ably extended by Col. Stephens, in the highly instructive experimental explosions during the last year at Sandy Hook. The experiments authorized by this very liberal appropriation will be made in part at Sandy Hook, and in part at Pittsburg or Cincinnati—each being under the charge of a committee of five engineers. The information which may thus be obtained may prove of inestimable public benefit, and we shall look forward to the inauguration of the experiment with great interest.

Coming Industrial Exhibitions.—It appears that the interest attaching to the eminently useful plan of systematically arranging, for display and inspection, objects of art and manufacturing industry, is growing with each year, and in no country does it seem to have obtained such unbounded popularity as in our own. The following summary of present and prospective exhibitions will give an idea of the interest centering in them.

Leaving out of consideration the colossal display which is at present attracting the eyes of the world to Vienna, we find at home that the American Institute proposes to open its yearly exhibition at the building on Third avenue, between 63d and 64th streets, in New York City, on the 10th of September next, of which the management have taken the precaution to give timely notice to those wishing to participate as exhibitors.

The city of Cincinnati proposes to repeat this year the very successful exhibitions held for three successive years under the auspices of its several trade associations and the Ohio Mechanics' Institute, the time for the opening of which is announced for the 3d of September next.

The cities of Louisville and Newark are to be placed in the list with a similar intention, while from Chicago comes the announcement that, to properly commemorate the second anniversary of the historic calamity which recently befel her, no less than to indicate to the world the wonderful recuperative power which has already effaced the traces of this misfortune, a grand inter-State exposition is proposed. The date for the opening of this exhibition is stated to be fixed for the 1st of September, the work of erecting buildings necessary for the purpose being already in hand.

Artificial Magnets.—M. Jamin recently exhibited a magnet constructed by himself, which carried upward of twenty-two times its own weight. The magnet in question weighs two kilogrammes, and supports forty-five kilogrammes. The usual carrying capacity of artificial magnets is less than three or four times their own weight; though there have been isolated instances in which much greater power has been obtained. It is worthy to notice that M. Jamin has followed to its limit the plan of employing a number of plates—which is commonly followed where a strong magnet is wished. The only variation in his method from that usually employed seems to be in the fact that, instead of employing in his composite bar a number of thick plates, he has used a great number of very thin plates, superposed—each very thoroughly magnetized.

Hydrofluoric Acid.—Mr. A. P. Stuart gives the following hint which may prove of value to those who have occasion to make frequent use of this reagent in their laboratory work. It is well-known that in the production of this acid by the action of sulphuric acid on fluorspar, there remains behind in the platinum or lead retorts an extremely hard compound, which cannot be removed without great difficulty.

According to the author, this disagreeable consequence can be obviated by employing, instead of fluorspar, a mixture of equal parts of fluorspar and gypsum. The residue, in this case, left behind in the retort, may be readily removed upon the application of water.

A New Polishing Agent.—Dr. Elsner states that the accidental use in his household of the water which had been employed to boil potatoes for cleansing silverware, led to the unexpected result that this was much superior in its cleansing action to the polishing powders so generally employed. It was found that by simply rubbing the article with the fine deposit of potato flour, that it took on an excellent polish, without the disagreeable necessity of subsequently using the brush to remove the material, as it is necessary where powders are employed instead.

Fluorine and Sodium for Cold Short Pig.—An experiment in removing phosphorus from iron during the puddling process by treatment with a small percentage of fluorspar in the puddling furnace, is announced as having been eminently successful at the iron works at Thale in the Hartz. The difference of opinion amongst metallurgists, concerning the efficiency of "medicines" of any kind, are well known; but any well-authenticated results which have been obtained with their employment, warrant careful attention. In the case here referred to, the pig iron used in the conversion was of the brand known as Ilseder, which ranks with the worst of the German irons, in virtue of its notable percentage of sulphur and phosphorus.

The iron in question was puddled along with about 1½ per cent. of fluorspar, and the product is claimed to have been a fibrous iron, which, when rolled, did not exhibit the slightest trace of cold-shortness.

Apropos of the same subject, a small application of sodium has been suggested by MM. Girard and Toulaire, who propose to conduct the vapors of sodium or potassium into molten pig iron, and then decomposing the alloy thus obtained by means of a blast of air. It has been declared by Springmühl that, by addition of sodium to molten iron in a crucible, and lixiviation of the product in water, a very pure and soft iron may be obtained, which, on second melting, loses its porosity.

It has been stated by experts that in the event of any large demand ensuing for sodium, it can be prepared in quantity at a cost but little, if at all, greater than that of zinc.

The Coming Transit of Venus.—The following is the description given of M. Janssen's method of photographing the apparent contacts of Venus with the sun's edge. The sensitive plate of the apparatus is in the form of a disc, fixed upon a plane which rotates upon an axis parallel to that of the telescope. The disc is eccentric, so that the images are formed near its circumference. Before it, a second disc, forming a screen, is arranged, in which is made a small aperture in order to limit the photographic impression of the portion of the solar image, to around the locality where the contact takes place. The circular plate which carries the sensitized plate is toothed and placed in communication with a small escapement apparatus, actuated by an electric current.

At each second the pendulum of the clock interrupts the current, the plate turns ahead one tooth, and thus exposes a fresh portion of the plate to receive an impression. If, therefore, the disc has 180 teeth the plate will receive 180 images of the solar edge. The photographic work can thus be begun a minute and a half before the presumed instant of contact; then when the series relating to the first contact is obtained, the sensitive plate is withdrawn and another substituted, which gives the second contact, and so on for the four.

Testing for Sulphur.—In the German Chemical Society's *Berichte*, Mr. B. Tollens calls attention to an important omission in the text-books and guides for chemical analysis, concerning a precaution which it is necessary to observe in testing for the presence of sulphur.

The simplest process, and the one universally followed, to detect its presence qualitatively, consists in bringing the test specimen, mixed with soda, upon charcoal, and heating the same in the reducing portion of a blowpipe flame.

The omission to which the author calls attention in a brief notice, and which may often lead beginners astray, lies in the fact that it is nowhere stated that the gas flame cannot be employed for this purpose, but only the flame of an oil lamp or candle, since the gas flame of itself contains invariably so much sulphur, that by directing it upon pure soda for a minute the resulting mass will perceptibly blacken silver.

A Chemical Experiment.—To prove that the inner, dark portion of an illuminating flame contains combustible gases, the general practice with experimenters is to insert into that part of the flame a glass tube, so inclined that a portion of these gases shall rise into it, and thereupon igniting them at the farther extremity of the tube, or leading the contents of the tube by an aspirator into a convenient vessel, when its combustibility can then be directly tested. Mr. Heuman has communicated to the German Chemical Society another method, and a simpler one, of accomplishing the result, which seems worthy of notice.

He recommends taking advantage of the well-known fact that a mixture of about 4 parts of chlorate of potassa and 1 part of strontium nitrate. heated to fusion, will burn with a very intense flame in hydrogen or illuminating gas, when once the ignition of the oxygen liberated from this mixture is effected by contact with a flame.

To perform this very pretty experiment, the author states that it is only necessary to fuse a small quantity of the mixture in question in a little spoon at the apex of a luminous gas flame, and then to lower it into the dark portion, when a brilliant combustion will immediately ensue; while, when removed to the luminous portion of the flame, or taken altogether out of it, it is at once extinguished.

The Intra-Mercurial Planet.—Mention was made in a late number of the "Journal" of the observation of Mr. Cowie, at Shanghai, in China, of the passage across the sun's disc of a peculiar object, which he infers to have really marked the transit of a planet nearer to the sun than Mercury, the existence of one or several of which have for some time been suspected by certain astronomers. Similar observations to that of Mr. Cowie have been previously made and a similar inference drawn from them by several observers, though none of the reputed discoveries have been regarded as sufficiently convincing to establish the fact.

It will probably require either that the planet or planets shall be actually seen during a solar eclipse, or that the existence and transit of the same shall be demonstrated and predicted from mathematical calculation, based upon perturbations of its neighboring planets, or other data, before the evidence shall be deemed sufficiently conclusive.

It is, however, interesting to note the fact that Prof. Daniel Kirkwood has taken the observation of Mr. Cowie and, employing it in conjunction with the recorded dates of similar phenomena, has arrived at the conclusion that they indicate the existence of an interior planet in close proximity to the sun, whose year, or time of revolution, is 34 days, 22 hours and 32 minutes.

Editorial Correspondence.

Editor of Journal of Franklin Institute:

MY DEAR SIR,—As you are recording novelties in the "Journal," I take the liberty to send to you a plan for the attachment of the small mirrors upon the tuning-forks to be used in projecting Lissajou's curves. With the forks made by König it is hardly possible to get a projection of the curves more than six or eight inches square, especially if a lens is used to focus the beam of light. While making a pair of these forks for demonstration in the lecture-room, I stumbled upon a result that surprised me, and in every way proves itself superior for such a purpose to the common method of attaching the mirrors to the forks, viz., by screwing them into the fork.

As I have no convenience for drilling iron, I tried to fasten the round glass mirror to the fork with the cement known as marine glue. While using the forks thus fixed, one of the mirrors accidentally was struck and loosened, when the line, that before had been but a foot long upon the screen, suddenly spread out to *ten feet.* The glue was a little elastic and permitted the mirror to have an angular motion of its own. I took the hint, and mounted each fork with the glass, separated from it by a strip of india-rubber, so as to allow an angular motion in the same plane as the vibration of the fork, and the elasticity of the rubber can be utilized so as to give an angular motion many times greater than that of the forks. So fixed, I can easily get a band of light eight or ten feet long, or twice that if both forks vibrate in the same plane, while figures resulting from the combined movements at right angles are magnificent and, I think, unparalelled.

This great size does away with the necessity for a lens, and if sunlight is used reflected from a porte lumiere, and passed through a small hole in a card but three or four inches from the first fork, there will be no lack of definition. All the smaller ratios, as $\frac{1}{1}$, $\frac{2}{1}$, $\frac{3}{2}$, $\frac{5}{4}$, &c., can be seen and *counted* by an audience of a thousand. And, more, a pair of such forks, with everything necessary for such an exhibition, can be made for ten dollars.

A. E. DOLBEAR.

Physical Laboratory, Bethany College, W. Va.

A GEOMETRICAL SOLUTION OF SOME ELECTRICAL PROBLEMS.

By Prof. Edward C. Pickering.

The analytical solution of the following problems is always a little complex, considering the simplicity of the results, and therefore unsatisfactory to the student. It is hoped that the following geometrical method may prove both useful for purposes of instruction, and suggestive of a simple solution of other more difficult problems.

The method employed is to represent by horizontal distances or abscissas, electrical resistances, and by ordinates the potentials of the various parts of an electrical circuit. Thus in fig. 1, neglecting the lines to the left of AA', suppose AC equals the total resistance of the circuit, and that the battery has a potential AA'. If, then, one pole is connected with A, and the other with the ground at C, the potential of any point B may be found by drawing the straight line $A'C$, and erecting the perpendicular BB'.

Wheatstone's Bridge.—Four resistances, M, N, O and P, are connected together, end to end, two opposite junctions being connected with the poles of a battery, and the other two with a galvanometer. The needle of the latter will not be deflected when $M : N = P : O$. To prove this, lay off fig. 1, $AB = M$, $BC = N$, $ED = O$ and $DA = P$. Suppose the battery connected at A, erect the perpendicular AA' equal to its potential, and draw the lines AC and AE. Draw also the lines BB' and DD'. They will represent the potentials at the terminals of the galvanometer, and will be equal if no current passes. But $AA' : BB' = M + N : N$ and $AA' : DD' = P + O : O$, and if $BB' = DD'$, $M + N : N = P + O : O$, hence $M : N = P : O$.

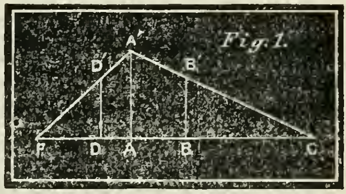


Fig. 1.

II. *Poggendorff's Method of Measuring Potentials.*—Let E' equal the potential of the battery to be tested, and E the potential of that with which it is to be compared, and which is taken as a standard. The galvanometer is connected with the latter battery, interposing a resistance to reduce the current. Now connect the two terminals of the other battery with the galvanometer, so as to pass a current through it in the opposite direction, and vary the interposed resistance until the needle comes to zero. Call G the resistance of the galvanometer, and R that of the standard battery and resistance; then there will be equilibrium when $E : E' = G + R : G$. To

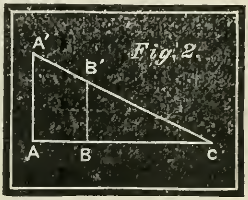
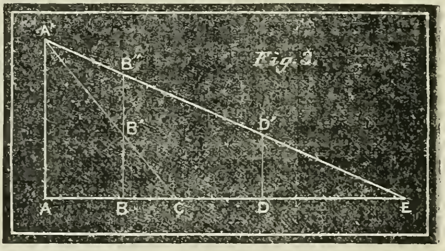


Fig. 2.

prove this, let AA', fig. 2, equal E, $AB=R$, and $BC=G$. Let DD' also equal E'. For equilibrium DD' must be equal and opposite to BB'. But $AA' : BB' = AC : BC$ or $E : E' = G+R : G$.

III. *Thomson's Method of Measuring the Resistance of a Battery.*—This method, although much more recent than the others, is scarcely of less importance. The galvanometer is connected with the battery, and a resistance R interposed, to reduce the deflection. R is then removed and the galvanometer shunted, until precisely the same deflection is again produced. Call B the resistance of the battery, R' that of the shunt, and G that of the galvanometer. Then $B=\frac{RR'}{G}$. In fig. 3, let AA' equal the potential of the battery, $AB=B$, $BD=R$, $DE=G$. The current passing through the galvanometer will then in the first case be measured by DD'. When the galvanometer is shunted its resistance is reduced $\frac{GR'}{G+R'}$. Lay off BC equal to this quantity. The current in the second case evidently equals BB', and since the deflection is the same in both cases, we must have $DD'=BB'$. Now $AA'-DD' : DD' = B+R : G$ and $AA'-BB' : BB' = B : \frac{GR'}{G+R'}$. Hence $B+R : G = B : \frac{GR'}{G+R'}$, or $GB(G+R') = GR'(B+R)$, $G^2B+GBR' = GBR'+GRR'$ and $GB=RR'$. Hence $B=\frac{RR'}{G}$.



In the same way the deflection which will be produced in any given case may be determined, or the resistance which should be inserted to render it a maximum. The many applications of this method are, however, so obvions that further illustration seems unnecessary.

May 13th, 1873.

Franklin Institute.

Proceedings of the Stated Meeting March 19, 1873.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the chair.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held March 12th, 1873, the following donations had been received into the Library:

Zones of Stars observed with the Meridon Transit Instrument, at the U. S. Naval Observatory. From the Superintendent.

Zones of Stars observed at the U. S. Naval Observatory with the Mural Circle. From the Superintendent.

The Nineteenth Annual Report of the Chief Engineer of the Cincinati Fire Department. From the Chief Engineer.

Second Annual Report of the Board of Commissioners of the Department of Public Parks, New York City. From the Board.

Report of the Inspector of Buildings of Boston, Mass. From the Inspector.

Thirty-fourth Annual Report of the Boston Fire Department. From the Chief Engineer.

Annual Report of the Chief Engineer of the Water Department of the City of Philadelphia, for the year 1872. From the Chief Engineer.

Report of the Board of Public Charities of the State of Pennsylvania, 1872. From the Board.

Report of the Proceedings of the Meteorological Conference at Leipsic. From the Meteorological Committee.

Monthly Notices of the Royal Astronomical Society, January, 1873. From the Society.

The reports of the several standing committees were presented and accepted.

The several special committees reported progress and were continued.

The President next announced the paper for the evening to be upon the Horse-Power of Steam Boilers, by William B. Le Van. The same is published in the Journal of the Institute for June, 1873.

The Secretary then read his monthly report on Novelties in Science and the Mechanic Arts.

The President presented to the notice of the members a reading table, manufactured by the students of the Worcester Free Institute of Industrial Science, and made some remarks concerning the history, plan and present condition of the school, and upon the bearing of this and similar modes of training upon the character of the mechanics. The President's remarks are published in the Journal of the Institute for April, 1873.

Under the head of new business, the President announced the names of the following gentlemen as members of the Committee to fix a factor of safety in carrying steam pressure, in obedience to resolution offered at the February meeting of the Institute: Mr. Robert Briggs, Chairman; Messrs. Wm. B. LeVan, J. H. Cooper, L. Schütle and W. F. Durfee.

Mr. Bartol offered the following preamble and resolutions:

Whereas, The use in lamps of the various lighter products of petroleum or coal oil results in an alarming number of deaths and conflagrations, which disastrous results are rapidly on the increase; and, *whereas*, from the experiments of our worthy Secretary, it appears that less than one per cent. of the various oils or illuminating compounds sold in this city are fit for use in lamps; be it

Resolved, By the Franklin Institute of the State of Pennsylvania, that it earnestly recommends and petitions the Legislature of the State to pass an act or acts embodying the following points: To appoint a competent commission to investigate and determine some satisfactory test whereby it can be ascertained which oils or compounds are safe to be used in lamps and which are unsafe. To make it a penal offence to manufacture, compound, sell or knowingly use any oil or compound that will not stand the required test, and that in case of death resulting from the same, the guilty person or persons shall be liable to conviction for manslaughter. And further be it

Resolved, That the Secretary be and is hereby instructed to furnish a copy of these resolutions to the Speaker of each House, and to the Governor of the State.

The resolution was carried.

Mr. William B. LeVan moved the following:

Resolved, That the Publishers of the Journal of the Franklin Institute be directed to publish with each number, on the first page, the following:

NOTE.—This society is not responsible, as a body, for the opinion advanced in its publications.

And the mover supported his resolution by remarks upon the subject, which elicited a discussion.

The motion was lost.

Mr. Henry Cartwright, seconded by Mr. J. E. Mitchell, offered the following:

Whereas, An International Exposition of Arts and Manufactures will be held in Vienna in May next, under the auspices of the Austrian Government, and, as in view of our Centennial Exposition in 1876, much valuable information may be gained by a personal inspection of the Vienna display, it is therefore

Resolved, That the proper officers of the Society are requested to appoint one or more of its members as delegates to represent the Franklin Institute at the Vienna Exposition, and that they be requested to report to the Institute on the same.

The resolution was carried, and the meeting thereupon adjourned.

WILLIAM H. WAHL, *Secretary*.

Civil and Mechanical Engineering.

THE CONSTRUCTION OF IRON SHIPS.

By Samuel Holmes.

In the mechanical arst, during the last half century, the forces marshalled by mind have been making great marches in the path of victory. Stronghold after stronghold of the enemy prejudice, has been captured and broken down; yet still the fight continues, and many a whitened warrior may be seen shaking the fragment of his blade and shouting victory, as he lives to witness the obdurate foes of his youth and ripe experience succumb. To sit at the feet of such spirits is to become inspired, and so, rising with firm resolve, many are buckling on the armor of enterprise, and longing, like Alexander, for worlds to conquer.

Were it possible for the eye to take in the iron fleet of the world, the beholder would surely exclaim, "Here must be perfection, if there be truth in the assertion that experience perfects." But how can we reply to the exclamation? Shall we soothe by saying yes, and violate our conscience? No! We look over that vast fleet, and, despite the efforts of one or two earnest mechanical minds, we trace in the multitude of ships a multitude of sins against mechanical arrangement and accuracy.

As we live in an energetic and practical age, the poetry surrounding the wooden ship and the melancholy in her chips is fast dying out, while the noisy chorus of ringing hammers and the clatter of machinery, the servants of the iron age, usurp the place.

It is not our intention to discuss the wooden ship. She only exists because she is cheaper in first cost over her iron rival: so we dismiss her with respect for past services, but disown her for the requirements of the present day, with her solitary, though not lasting advantage.

Iron, strong in itself and so capable of retention of strength in its fastenings, becomes strong in argument through this intrinsic merit; and small as was the iron vessel's beginning, it has gradually grown from the river boat to the ocean mail steamer, and may be found speeding over the main to every clime, reaping the richest profits which are offered to allure the enterprising spirit.

I say iron must uphold a country's marine, because steam is the world's requirement, and economy the ship owner's. In the first place, the iron ship is lighter, and will, accordingly, carry much more on the same draft and displacement, and has a far greater capacity to stow the increase; secondly, she is stronger, and will endure much more hard work; thirdly, she costs much less for repairs, and has a longer life; and fourthly, she insures at a cheaper rate.

I might continue the enumeration of the advantages of iron over wood, but prefer to support my position by quoting the rapid increase of iron tonnage, which is *the* practical argument, and the one best calculated to give the true position of affairs.

Taking Great Britain as an example, the following table gives the comparison:

	Iron Vessels.		Wooden Ves.		Composite Ves		Remarks.
	No. of Vessels built.	Tons.	No. of Vessels built.	Tons.	No. of Vessels built.	Tons.	
1851	55	15,826	617	133,811			745 per cent. more wood tonnage than iron.
1862	219	106,497	740	115.955			8¾ " " " " " "
1868	309	205,716	378	80,448	4	2,250	155 " " iron " " wood.
1871	510	347,374	502	41,699	10	1.985	733 " " " " " "

From this tabulation it appears that iron tonnage has increased the enormous extent of 2094 per cent. in twenty years, whilst wood tonnage has decreased 68 per cent. during the same period. These figures undoubtedly beat the tattoo of decay and death to wooden ships; an opinion which is substantiated by observing how the poor craft is forced out of the best trades of the shipping world.

Wood had the advantage of lead in the Atlantic trade, but the iron ship has starved her out of competition, the *economy* of the iron vessel being unqestionably the cause of this rapid development.

To discuss this important shipping question in its relations to American interests, we must know positively where the obstruction to American shipping lies, in order to attack the evil with certainty and success. A pamphlet, issued a short time since, entitled "Shipbuilding and Ship-owning by Americans in Connection with Foreign Trade," emanating, I believe, from a leading Philadelphia firm of ship owners, traces the disadvantageous position in which Americans are at present placed to three causes:

First, "The risks arising during the late war;" second, "The substitution of iron for wooden vessels;" and third, "The cheaper cost of building iron vessels elsewhere than in America, together with the larger credits which the heavy capital of foreign builders enables them to accord to purchasers." The pamphlet then proceeds to state, "the problem to be solved is, how best to neutralize the third cause," and I am happy to know it is in my power to suggest and develop a plan to aid the solution of this problem. With one more quotation from the above named pamphlet I pass on.

It states, "It is plain that an unaided owner cannot employ American ships unless their *cost is reduced.* It is equally plain that of the various elements of cost, builders cannot seriously lessen either that of labor or capital, but only those which may be cheapened by *mechanical appliances.* At present, however, they lack financial strength, and the stimulus and opportunity for testing inventions afforded by a large and regular demand for their work. To whom can they look for this demand? Not to foreigners, who can buy cheaper abroad. They can effect it only through their own countrymen." This paragraph cuts right at the heart of the matter, lays the question bare; then with patriotism bids the ship-builder look to the American ship-owner. We feel the time is indeed auspicious, to tell the ship-owner he can buy his vessel at a reduced cost—and being told, good faith must follow.

Here, then, is the sore spot; *cost of construction* is the great obstacle in the way of the American iron ship. But now national pride is aroused, and, despite this excessive cost, our pioneer vessel lies at her wharf loading for Liverpool. However, gentlemen, we are here this evening to unitedly throw a stone at this Goliath, and I hope to be able, before I close, to bring conviction to your minds that the question is virtually settled, and requires simply practical development.

Ship owners have inspired the newspapers, and the latter have stirred many hearts in the country with the desire to see the American flag represented on the ocean as befits the dignity of the nation. This wave of desire has passed on to Washington, and has an earnestness of meaning that is unmistakable. But let us have a care, since too much precipitancy is often ruinous.

Let us review what is being asked, and in the first place we find one clamoring for a monopoly, a second sueing for bounty, and a third asking for subsidy.

In regard to this aspect of things, we must say, firstly, and with emphasis: We don't believe in monopolies! A monopoly implies, indirectly, the suppression of individual effort. Individual effort implies competition, and competition is the life of trade.

The scheme of bounties we regard as dangerous, since there can be little justification in Government giving gratuitous aid to any manufacture, or business undertaking, especially when it questionably seeks it. Were such a thing absolutely necessary, we think ship-building and ship owning, through its national character, would be better justified in seeking and accepting such aid than anything else; but this is qualifying, and the necessity does not appear.

It is the duty of the Government to pay an equivalent for value received, so give subsidy where a mail is carried, or where other work is performed; but beyond this, it is the writer's opinion, we are better away from Government aid, except the protection in national rights.

Viewing the subject of our commercial marine as a ship-builder, I intend speaking from a practical standpoint, and presenting for your consideration some ideas of a practical nature on the subject.

I may state at once that in seeking a remedy I go to the root of the matter, that is to the ship herself; and shall seek to place my finger on the weak places of iron ship construction, and develop ideas and designs which, you will discover, deal directly with material and labor, items which are the basis of cost.

The first I reduce in weight, by using more suitable sections, or forms of iron, and by placing the iron in the vessel so as to give the greatest strength to her structure. The second, I reduce in cost by performing with machinery what is now done by hand. I here give an outline of the propositions which I hope to sustain, but before proceeding with the details of my own views it is needful that defects in the present method of construction should be pointed out.

When the wooden ship-builders of half a century ago turned their attention to iron, as a material for ship-building, they possessed but an imperfect knowledge of the material with which they had to deal. Accordingly, as was natural, they followed the system of building with which they were familiar. That system is commonly known as the transverse framing system; that is, the frame is run across the ship right angles to the keel, and extends up to the gunwale in a vertical direction. The necessity for such a plan of construction in a wooden ship arises from the fact that the planking has no edge connection with itself; therefore it must have an indirect connection, attainable only through the framing, making the framing, therefore, the most important part of the structure.

Wooden ship builders, imbued with this idea of transverse framing, and being familiar with its execution on the loft floor, carried it out in practice when their attention was given to iron.

In her main features, the iron ship of to-day is the same as the iron ship of years ago. We, of course, find some improvements. These, however, may be traced as much to the iron manufacturer as to the ship-builder, since it is now possible to obtain what was before impossible, namely, material of almost any dimensions. Plates now go on the ship of quadruple their former size, giving a better arrangement of butts, and a reduction of fastenings, and though the plates are worked as "in" and "out" strakes, instead of being clinker built, yet the original principle of ship construction remains. Improved machinery has added its quota, and has greatly aided in bringing the iron ship of to-day to its advanced position.

In reviewing the iron ship as now built, we find her keel in most cases, when draft of water permits, of solid bar iron, say $8\frac{1}{2} \times 2\frac{3}{8}$ inches in a 1,000 ton ship. These bars are usually connected by scarphs, in length nine times the thickness of the keel, and are rivetted together by three or four small rivets, which would break were the keel even partially suspended and its weight allowed to test them. This fact shows unfavorably the value of a solid bar keel, strong in its several pieces, and weak in its connections. But we are told it is strengthened by the flange of garboard strake, which is bent in accordance with the angle formed by frame and keel. Yes, it is strengthened, of course; but do we get the strength out of it which we should fairly expect from its weight? By no means. At the scarph, it is like a double plate with its butts shifted only $21\frac{3}{8}$ inches apart; were it two plates, instead of a solid bar, in point of strength it would take precedence over the bar, as the butts could be shifted at least nine feet apart, and opportunity afforded of connecting it with centre keelson.

We appreciate the advantages a ship derives from a keel, but do not appreciate this arrangement, which is little more than five tons of packing or material without mechanical application.

There are other improved descriptions of keel adopted, but the one described is the one in general application, where draft of water permits.

The frames, as past and present practice use them, are of angle iron in accordance with size of ship, and run across the keel at right angles, and vertically up the side; that is, are transverse in their direction.

Each frame, as a whole, is composed of three parts: the frame proper, or angle iron coming against shell; a floor plate, the name given to the plate which runs across the bottom, and turns up the bilge to a height of twice the centre depth; and a reverse frame running across top of floor plate and up the side of ship, attached to moulding edge of ship's frame at inner side. These are all securely rivetted together, and are spaced from 21 inches to two feet apart, all fore and aft the ship.

There has been a gradual tendency to stretch out these frames, as the fact has become manifest that the *skin resistance is the great point of strength in an iron ship.* Lloyd's early rules, and the first practice of ship-builders, approached as nearly as possible the wooden ship-building idea of close framing, which is requisite in a wooden ship, owing to the poor description of fastening and the absolute necessity of obtaining as much fastening as possible. With iron it is, however, totally different, and how ship-owners can require, and still more wonderful, how ship-builders will build, except under protest, vessels on a system that ignores and degrades science, when they have the knowledge that the ship's strength is *in her plating*, surpasses conception.

I appeal to you, ship-owners of Philadelphia, to sweep away this evil. You are paying more for your vessels than is necessary, and for your money you are obtaining anything but mechanical structures. You are obtaining ships which, despite the British Lloyd's, the Liverpool Registry, the French Veritas and the American Registries, or the approval of any other body, is a libel on the dictionary to call first-class, without adding the saving clause—*Transversely Framed Ship.* A ship, first-class, that is holed all round her at each frame, the distance apart of holes being merely six inches, and she subject to racking and twisting at sea, as she passes from mountain to mountain of water, straining and straining again! Can any one point me out a stronger argument in favor of the *tower of excessive strength possessed by the present iron ship, through the introduction of excessive material, than this: that she can be made rigid by the introduction of a frame, and at the very point of rigidity can be weakened by punching away her material until she is at each frame $\frac{1}{8}$ weaker than the solid plate?* Yet, professedly, the frames are put in for strength. Delusion! Once overlook the fact that the shell is the main strength, is *the* strength of the vessel, and error need not be wondered at.

The framing of an iron ship is but an auxiliary; why, then, make the plating subservient to it? Why weaken the plating for the sake of it? Let us have no more such work; tear out the inner structure, and dispose the iron to better advantage.

Having spoken, as I have, of the general framing of the ship, what shall I say—what are you prepared to hear respecting the Bulkhead frames that are introduced in iron ships? These frames generally count two amidships, one before and the other abaft the engines. They are usually double frames, that is, double angle irons, back to back, with bulkhead plates between. The object of the bulkhead is to give the ship water-tight compartments. It accordingly has to be caulked, and made thoroughly water-tight.

Experiment proves that, in order to make a properly water-tight joint in rivetted work, the rivets must not be spaced more than four diameters apart. This accordingly necessitates the punching of frame and plate with holes, not six inches apart as in rest of framing, but three inches apart, thus reducing the strength of shell about $\frac{1}{4}$ of solid plate.

I have referred to the rigidity of an ordinary frame, but how can its rigid power compare with that given to the frame of a bulkhead which is plated solid across the ship and stayed by angle irons. It is true attempts are made to extend the rigidity over the shell and reduce the effect of close holing by introducing liners in way of outside strakes, and knees alternately on forward and after side of bulkheads, thus partially attaching bulkhead to shell indirectly; but with the shell weakened nearly one-fourth, and a rigid frame calling the attention of every strain to it, we need not feel surprised should we hear of a long, shallow steamer breaking off at her bulkheads.

Nor need we be surprised at hearing of a *full* bowed steamer being stove in by ice in coming up the Delaware, when we remember that, by placing the frames one distance apart all fore and aft, as we approach the ends, there is less plate stayed by frames than amidships; for while the frames are the same distance apart on a square line, yet on the run of the water line the distance is greater, by reason of the fact that the base of a triangle is less than its hypotheneuse.

Transverse framing has yet another disability, namely, the bevelling which it has to endure to enable the outside flange of frame to be flat upon the plate at the ends of vessel. This bevelling commences immediately the side of a ship alters from her midship shape, and increases rapidly at the ends, where the iron is greatly injured by being opened from the right angle to the obtuse angle required.

So severe has the punishment been to the metal, that I have frequently seen the angle split right open in the throat, which is the place of greatest strength. The weakening had gone on by degrees, as the bar was opened or bevelled until the iron finally gave way. (A specimen of bevelled iron thus split was here exhibited by the speaker.) It would be interesting to know how many frames in the present iron ships afloat were just on the point of splitting open when the workmen eased up on them. This state of things is not right. It is a matter of grief to a true mechanic to see material abused, and a hardship to be compelled to put iron into a ship which he knows to be ruined. If the material is not giving proportional strength for weight take it out ; change the section of iron, change the arrangement, change the system, change the modes of working the material, or change yourself if you can't do it.

I have pointed out how a ship is weakened longitudinally by transverse framing—weakened in the line of desirable increased strength, as she would certainly break in two through leverage of length were she to give way at all, as her length is from seven to nine times her breadth, and from ten to fifteen times her depth.

In present mode of construction we have a strange anomaly. *The ship is weakened in the direction in which she is already the weakest*, i. e., *longitudinally, then longitudinal strength is applied in the form of keelsons to regain her loss of strength.* Certainly a brilliant mechanical device, but certainly a most un-American mode of procedure. We should not weaken our ship, then we shall not require *extra material and fastenings ;* and if the material we do use is made to fulfil more purposes than one, we reduce the weight and cost, and exhibit skill in place of bungling.

The keelsons now employed to give longitudinal strength are various in form, and consist of, first, a middle line keelson ; the general form, when a bar keel is used, being that of a plate of certain depth and thickness, with double angle irons at top and bottom. This keelson is connected to double angle irons on top of floor plates at middle line by four rivets to each floor, that is, four rivets for each space of twenty-one inches, fore and aft distance. This shows up a lattice arrangement, for the keelson bridges the transverse floors, or comes in contact with them at distances of twenty-one inches, thus piling up the iron, instead of being a floor itself, running fore and aft, thus being floor and keelson in one, saving weight and having an equally spaced arrangement of fastenings, instead of a cluster of fastenings, then a lengthened space, and again another cluster of fastenings. The middle line keelson is sometimes formed as a box, at other times worked intercostally between the floors, which gives a more compact arrangement. This intercostal arrangement is usually supplemented by being extended above the floors, either in the form of middle line keelson as described, or cut off at a level of lower angle irons on top of floors. Another form of centre keelson is that known as a centre through plate keel and keelson, which is a deep, continuous plate, having the floors cut at centre to allow it to run all fore and aft. There are double angle irons at bottom running fore and aft; again similar ones are fitted on a horizontal plate, on top of floor, at each side of centre, connecting keelson and floor through the medium of horizontal plates. A further connection between floor and keelson is effected by vertical angle irons in the corners, so that the whole is efficiently bound together. This strength is, however, made up entirely by additional weight, as indeed is the longitudinal strength obtained by all. The other keelsons in the ship, such as side intercostal keelsons, at half floor, are composed of plate and angles running fore and aft. Lower and upper bilge keelsons are formed of double angle irons, back to back, and rivetted to inside of frame or top of floor, and also extend fore and aft. I wish it distinctly seen that to obtain longitudinal strength, the *strength most required*, owing to length being greater than breadth and depth, the present system of ship-building is to first weaken the ship one-eighth at section of each frame and one-fourth at section of each bulkhead, making her at the same time more rigid at these points and liable to receive a strain there. After she is weakened, several tons of material, in the shape of keelsons, are put in to give her back her reduced strength, which, however, falls short in restoring the loss, as the sectional areas of material will show. In a 1000 tons ship, built on the transverse system of framing, the sectional area of shell plating at midship section equals 640 square inches, which is reduced about one-fourth in way of bulkheads, by punching the frame all round to make bulkhead watertight; this reduction equals 160 square inches. Now, to keep up the original strength, we ought to make up the deficiency of 160 square inches which is punched away, and also give an excess to strengthen the ship longitudinal, as she is weakest in that direction. What is the present practice? It is this: A middle line keelson is required of plate 14 inches deep by $\frac{11}{16}$ inch thick, having at top and bottom double angle irons $5 \times 3\frac{1}{2} \times \frac{8}{16}$, altogether giving a sectional area, without deducting punchings, equal to 26·62.

There are also three other keelsons aside of double angle iron $5 \times 3\frac{1}{2} \times \frac{8}{16}$, back to back, which totals, taking both sides together, 51 square inches, and added to middle line keelson, gives a grand total of 77·62 square inches, added to sectional area by introduction of longitudinal keelsons, against 160 inches taken out by punching at bulkheads, *leaving a deficiency of* 82·38 *square inches on original strength of material, where the ship really requires an addition to original sectional area. The fact of introducing liners, too clearly exemplifies the general system of ship construction, which is to first weaken the structure, then throw extra weight of metal to alleviate the weakness.* In way of the ordinary frames, I stated that $\frac{1}{8}$ sectional area was punched away, which would make a deficiency by punching of 80 square inches, against an addition of 77·62 square inches by introduction of keelsons. We here see the vessel absolutely has no fastenings to strengthen her in accordance with the dimensional proportions of structure, for the extra fastenings introduced are thrown away in attempting to overcome the weakening of structure by introduction of transverse frames.

We can now reply to the question, how is it we can't build as cheaply as the British ship-builders? by answering that in spite of the increased cost of labor and material here, we are trying to emulate them in throwing away material and workmanship upon it—and *we* can't afford it.

But can we compete with them? Yes! I believe so, in a little time, if we don't follow them and their registry rules for the construction of iron ships.

Let us briefly show another help to this side before continuing our discussion. Two years and a half ago ship plates could be bought at £8,10 per ton at the other side; now I see the quotations range from £15 to £17 per ton, £15,10 being the latest quotation. Again, coal has gone up to famine prices, and labor is feeling the effects produced by the vessels it equips, carrying a steady stream of mechanics from Europe to America.

A careful estimate at exact present prices of labor and material shows a difference yet, in favor of British ship-builders, of 17·94 per cent., but so vast has been the reduction in two years that every effort must be made to secure, not only our own iron ship-building, but the iron ship-building for the world.

All this, however, should make us the more wary, for there are men of energy and vast ability at the other side, who will fight the battle with vigor; but for them to bring about a change is difficult, for the registries, serpent like, are coiled round and round the British ship. She must have a character, accordingly must be built to rule; thus the ship-builder and ship-owner are floundering in the mazes of a prodigious web. Europe is chained by a mass of rules that will hamper her almost inextricably in attempting to part company with old fashioned ways, while America is free in thought and has nothing to hinder her from taking the shortest cut to accomplish an object.

I must pass in review before you the upper part of the present ship, and as all the decks are similarly constructed and fastened, whether it be spar, main, lower or orlop deck, I shall confine myself to the upper deck. Here, at the deck, we discover the weakest point of the iron ship, but it is much better attended to now than originally; a few years ago the beams were of poor sections, or rather were made up of several sections of iron rivetted together; now, however, we find them of a good form of iron generally, known as **T** bulb. These beams run across the ship, and are attached to the frames by welded knees. The spacing of beams is from 3′ 6″ to 4′ 0″ apart, or one to each alternate frame. On top of the beams, at side of ship, is rivetted a stringer plate, which assists indirectly to connect beams with the side, as the stringer plate is connected to sheer strake by a continuous angle iron round the gunwale; much attention has of late been paid to this stringer plate, and rightly so, for this is the point where the ship is weakest, and I wish your attention paid to this part, as it still continues the weakest place, one of the chief reasons being that the beams are improperly connected to the side, as by their present fastening they give out their strength principally locally, whereas it should be distributed along the side, as I shall show it in describing my vessel. This is a matter of very great importance, for if a ship works at all, it is at the connection of side and deck, which is quite natural, as the strength of side suddenly stops here. I have known ships undergoing their periodic survey to have nearly all the rivets connecting beam knee to frame found loose, which practically points out the sore spot.

Great attention has lately very properly been paid to the pillaring of iron ships. Formerly there was no connection between the deck and the bottom of vessel, but now the different registries and builders make a decided point that all vessels have a pillar to each beam through midships and each alternate beam at ends, which acts as a tie or stay between the extremities of deck and bottom, and is of considerable value.

The latest addition to the iron ship is the iron deck; and in the transversely framed ship, weakened as the vessel is shown, it should be regarded as a necessity when the ship is of considerable length. A ship, in many respects, may be viewed as a box girder, only hitherto the fourth side has been left unenclosed; but by giving the vessel an iron deck we close all in, and complete the structure, *and the structure is good or bad, as you view the shell as the main strength, and stiffen it by auxiliaries at the inside, so as least to puncture the shell, giving the direction to your internal strengthenings that the form and dimensions of structure calls for.*

I have endeavored conclusively to show that the transversely framed ship does not come up to this standard, and before proceeding to develop a vessel that will respond to this call of excellence, we shall refer to the present mode of fastening, with its necessities and its faults.

Rivetting, as you are all aware, is the general method of connecting the various parts of an iron ship, and, as is natural, much attention has been paid proportioning and disposing the rivets, and giving to the plate the most efficient amount of lap. This system, the best hitherto practised, we shall, however, show to be far from perfection, as the vitality of the iron is injured by punching, which is the usual and best method of perforating the material in proportion to cost. Drilling has been resorted to, and has an advantage in point of strength; but it is too slow in its operation and too costly ever to be generally adopted. We say the vitality of the iron is injured by punching, and in support of this view I shall quote you briefly from E. J. Reed's work on "Ship-building in Iron and Steel." He says: "It has been established by direct experiment that when a row of holes has been punched in a plate, the tensile strength of the iron left between the holes is considerably reduced, whereas with drilled holes the strength remains almost unaltered. This is still more strikingly the case when holes are punched in steel plates, as shown in the preceding chapter. In iron plates the reduction in strength made by punching is considerable. For example, with the pitch of rivets usually adopted for water-tight work the tensile strength of the iron taken along a section through a row of rivet holes has been found to be from 16 to 18 tons per square inch of sectional area, whereas for the unpunched plates it has been upwards of 22 tons per square inch. *It will be obvious that the large factors of safety employed in proportioning the scanthings of the various parts of ships and other wrought-iron structures, render these experimental facts comparatively unimportant in relation to the consideration of the ultimate or breaking strength.*"

I request you to give these words your closest attention, as they bear full upon the point I contend for and build upon, namely, that the present transversely-framed iron ship is the most prodigal mechanical structure (in material and labor) to be found in the universe. Mr. Reed calls it possessing *large factors of safety*, and in that we agree with him, *very large*. Consequently, by rightly disposing her parts, weight and cost can be reduced. Mr. Reed continues: "But, with regard to the arrangement of proportions of butt fastenings, where the principal object aimed at is the preservation of continuity of strength, it becomes absolutely necessary to take into account the reduction of strength caused by punching, in order to arrive at a correct result. It may be added that, although this is not commonly done in arranging butt fastenings, in the investigation of rivetted work given further on in this chapter, we shall take this reduction of strength into account, and assuming the tensile strength of the plate iron lengthwise to be 22 tons per square inch before being punched, shall, in most cases, take 18 tons as the strength of the iron left between the holes after the punching has been performed."

To show you the exact difference between punched and drilled holes, I shall quote experiments made by Mr. W. H. Maynard, upon punched and drilled bars cut from the same plate, parallel to each other. The holes were about one inch in diameter, and drilled in two of the bars; the other two were punched so as to leave exactly the same section of metal in the plate as in the case of those drilled, namely, about 1·5 square inch at the part reduced. The results were as follows, showing a mean of 19 per cent. in favor of drilled plates.

Experiment.	Drilled bar broke with a tensil strain in tons.	Punched bar broke with a tensil strain in tons.	Difference in tons.	Difference p. c. in favor of drilled bars.
1st,	30½	26	4½	17
2d,	31½	26	5½	21
Mean	31	26	5	19

Mr. Maynard has also experimented upon the shearing strength of rivets in punched and drilled holes, as follows:

Five-eighth inch rivets in drilled holes.

Single shear = 26 tons per square inch.
“ = 26·4 “ “
Double shear = 39·2 “ “
Second experiment failed.

Five-eighth inch rivets and punched holes.

Single shear = 27·2 tons per square inch.
“ = 26·0 “ “
Double shear = 45·6 “ “
Second experiment failed.

Mr. Maynard says: “I consider the above as conclusive that rivets in drilled holes, subject to shearing strain, were about four per cent. weaker than rivets in punched holes under similar strain. I think that the sharp edges of the drilled plates have a greater tendency to snip off the rivets than the rounded edges of punched holes.”

The summary of his experiments seems to be—

1st. That drilled plates are stronger than punched by 19 per cent.

2d. That rivets are weaker in drilled holes than in punched, by 4 per cent.

3d. That the difference is in favor of drilled work by 15 per cent.

The great point to settle in rivetted work, however, is how does the rivetted joint compare with the solid plate? Is it as strong? Is it stronger or is it weaker? We must again resort to experiment to settle this, and find that Mr. Fairbairn has experimented upon single and double rivetted joints, with the following results:

Taking the strength of the plate as = 100, the strength of the double rivetted joint would be = 70, and the strength of the single rivetted plate = 56. This settles positively that rivetted work is inferior in strength to the plate in the proportions of 70 and 56 to 100; or less than three-quarters and very little more than one-half as strong for double and single laps respectively.

Rivetting, then, as a mode of fastening, must be abandoned, and I particularly desire your attention to the fact that I obviate this source of weakness, and save material and labor, thus cheapening the construction of iron ships by welding my ship, which brings her up to the original strength of plate.

I now pass from the transversely-framed ship to what has been done and can be done by other systems.

(To be continued.)

AMERICAN SOCIETY OF CIVIL ENGINEERS.

A regular meeting of this society was held at the rooms in New York, March 5th, 1873.

A paper on "Shaw's Gunpowder Pile Driver," by Samuel R. Probasco, C. E , of Brooklyn, N. Y., was read.

This Pile Driver was set at work in October, 1872, on a line of sheet piles for a reservoir dam in the valley of Parsonage Creek, Long Island. The material to be penetrated was sand and fine gravel, cemented together in places, so as to be hard and difficult to move with a pick, and like "hard pan." Clay was found below the water level of the basin; some borings showing it at fifteen feet below the surface; the lower stratum was tough and tenacious, and the whole material was under water.

The machine in form resembles an ordinary pile driver; a cast iron block, called a "gun," resting on the head of the pile, is bored out, and receives without windage a wrought iron piston attached to another cast iron block, called the "ram," which is lifted by explosion of powder in the bore. When the piston leaves the gun, a cartridge is thrown in, which, exploded by the heat freed by the piston in its descent, throws the ram upwards again, and forces the pile downward. The area of the piston is adjusted to the weight of the ram, which also is adjusted to the work to be done. Soda powder cartridges in cylinders of $1\frac{1}{4}$ to $1\frac{1}{2}$ ounce, coated with black lead and paraffine are used. The coating is expected to keep the powder dry, lubricate the gun, preserve the requisite tightness, prevent escape of gas, and cause the entire force to be exerted on the base of the piston.

The piston is made a little smaller than the bore of the gun, and has on its lower end a steel ring which fits the bore closely. The performance was as follows :—At first several explosions were necessary to lubricate the gun, which leaked gas so that the ram would not go to the requisite height to move the pile. After a few shots, the piston moved up regularly, and in its descent fired the charge, forcing the pile down and itself upward. When the resistance is slight, this machine may be economical, but when, as in this case, it required 300 blows from cartridges costing $2\frac{1}{2}$ cents each to force a pile down 15 or 16 feet, it cannot be called so. The gas from the explosions cut passages in the ring at the end of the piston, and thereby much lessened the power of the machine. The gun became hot from the rapid discharges, and the bore enlarged, whereby more gas escaped. Seven piles were driven with it—each costing more for powder than the contractor got for piles in place—when the machine refused to work. On examination, the steel ring was found furrowed by the powder, and the piston (diameter five inches) so bent by striking the bottom of the gun, as to be useless. The air-cushion relied upon to prevent this, was lost by the furrowing of the ring. The inventor, on being consulted, decided that the excessive consumption of powder was due to the piston being too small for the ram, weighing over 1700 pounds. The bore of the gun was then enlarged to receive a piston seven inches in diameter, and ten piles more driven, when the machine was again laid aside. The result of this trial was similar to the first, except that the piston was not bent. The gun got so hot as to fire the powder before the ram reached its place. Altogether, seventeen piles were driven to a depth of from fourteen to nineteen feet; requiring from 200 to 300 blows of 1½ ounce cartridges. An ordinary pile driver was then employed, with a hammer weighing 1800 pounds, and falling eight to ten feet. In this way, eleven piles were put down 15½ feet in ten hours—costing per pile no more than 100 blows from the powder machine. These 100 blows, at best, would put the pile down but ten feet.

The piling was spruce, from 10″ × 10″ to 10″ × 14″—20 feet long—with 2″ square tongue and groove. The piles were bevelled at the point on three sides, leaving the grooved side untouched. The groove was driven on the tongue of the preceding pile. The heads were protected with a light band. Seven piles were driven without shoeing; the eighth split, and showed the necessity of protection at the point. A cast-iron cup shoe, weighing about forty pounds, with a groove in it, and made with three bevels and one plain side, was found to stand the work. The tendency of the tongue of the pile to work up was obviated by twisting a chain tightly about the pile and tongue; a lever with rope attached was used for this purpose, the force being applied as the blow was delivered. Seventy-five piles were driven in this way to a mean depth of 15½ feet. By experience, 6″ more depth has been attained, which is about the maximum penetration in this kind of material, and this can only be done with the best of sound, dry spruce.

A brief discussion followed. After which a paper on "Rail Economy," by C. P. Sandberg, C. E., of London, England, in reply to the discussion had upon a former paper of his on the same subject, was read.

In that discussion it had been remarked, under the head of "Traffic

Capacity," that the weight on locomotive driving wheels, stated therein, differed from American practice—that on the Philadelphia and Reading Railroad, four tons on drivers were not exceeded for a 64 lb. rail, and that on the Erie Railway, 5½ tons had been found too much for a 70 lb. rail.

Mr. Sandberg herein replied that it would be interesting to know what weight the rail and the rail-joint would carry in the two instances mentioned. 6¼ tons on drivers on a 60 lb. rail, as stated in the table, and considered excessive, might not be so: the table showed that the 60 lb. rail of standard section with fishplate would carry 14 tons in the middle between three feet bearings, and 9¼ tons at the joint between two feet bearings. According to the table the maximum load on drivers on standard sections was one-third what the rail in the middle would carry, and two-thirds of what the rail-joint would sustain. In order to obtain the full value of the material, the joint ought to be as stiff as the middle of the rail. For this it is best to use the fishplate as thick as will not interfere with the tyre-flange; the angle should be as small as will permit an easy rolling of the rail. This angle is 11° and 15°, the latter for light rails, experiments having proved that the smaller the angle the stiffer the joint. With this fishing, the capacity of the rail at the joint is two thirds that at the middle, while with ordinary fastenings it is but one-fourth. In regard to the Erie sections, experiments have shown that this rail will bear at the joint but two tons, while at the middle it will carry ten tons; hence it is not strange that 5½ tons on the drivers proved disastrous. The necessity of sufficient thickness in the fish-plates is often overlooked. It is doubtless prudent to increase the number of drivers on American roads, but the statement that 6¼ tons on a 60 lb. standard rail section with standard fastenings, is excessive, should be modified. This load is not the most economical for working a line, but that to which an increase of traffic might extend.

Many European railways with a 70 lb. section have a joint carrying only six tons, owing to too large an angle and too thin a fishplate.

Improvements in Canal Navigation.—The Legislature of New York, we learn, has lately renewed, for the period of one year, the offer of one hundred thousand dollars for improvements in canal navigation, of which the general outlines, together with a description of the tests to be applied, has already been named in the Journal.

GAUGING OF RIVERS.

By Bvt. Brig. Gen. Henry L. Abbot, Major of Engineers.

(Continued from page 393, Vol. LXV.)

To try the formula arithmetically upon these new data, I have selected three observations; of which the first was made with especial care for a particular purpose; the second was in the deepest trough, thus having the velocity measured at the largest number of points; and the third (made by M. Baumgarten) was upon the canal Marseille with an earthen bed, the others being in wooden. To multiply the number of observations at each depth, as far as can be done without vitiating the curve by introducing the influence of the sides, I have taken a mean of the three central curves in the troughs, and of the five central curves in the canal. The following tables exhibit the data and the results obtained by applying the general equation on page 392, Vol. LXV. The depth of the axis is assumed so as to dispose the observations symmetrically upon the parabola: and the value of the maximum velocity is fixed by the condition that the sums of the observed and computed velocities shall be equal—throwing out in the second observation the lowest, and in the third observation the highest and lowest measurements, as probably vitiated by one or both of the above causes of error. The "strong wind" blowing at the time renders it extremely probable that this was the case.

Series 53. Sub-surface Velocity Observations.

Bed, poplar plank. Width, 2·63 feet. Depth, 0·82 feet. Mean velocity, 5·123 feet. Day calm. Depth of axis, 0·1 ft. or 0·12 of total depth. Maximum velocity, 6·113 feet.

Vertical plane	Velocity at following depths below the surface.			
	0·10 ft.	0·36 ft.	0·56 ft.	0·72 ft.
	ft.	ft.	ft.	ft.
Left of middle 0·36 ft.	6·076	6·010	5·472	4·289
Middle of canal	6·376	6·046	5·492	4·667
Right of middle 0·36 ft.	6·046	5 968	5·390	4·468
Mean	6·166	6·008	5·451	4·475
By formula	6·113	5·873	5·363	4·751
Discrepancy	+0·053	+0·135	+0·088	—0·276

Series 64. Expt. 2. Sub-surface Velocity Observations.

Bed, plank covered with strips 0·08 feet wide, spaced 0·16 feet apart. Width, 6·5 feet. Depth, 2·16 feet. Mean velocity, 3·111 feet. Wind very strong up stream. Depth of axis, 0·6 ft. or 0·28 of total depth. Maximum velocity, 3·981 feet.

Vertical plane.	Velocity at following depths below the surface.						
	0·10 ft.	0·43 ft.	0·75 ft.	1·08 ft.	1·41 ft.	1·74 ft.	2·07 ft.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.
Left of middle 0·66 feet...	3·763	3·872	4·034	3·953	3·679	3·316	2·296
Middle of canal...	3·929	3·982	4·112	4·034	3·873	3·471	2·389
Right of middle 0·66 feet.........	3·820	3·901	4·059	4·006	3·845	3·375	2·296
Mean..............	3·837	3·918	4·068	3·998	3·799	3·387	2.327
By formula........	3·893	3·971	3·973	3·900	3·745	3·521	3·220
Discrepancy......	—0·056	—0·053	+0·095	+0·098	+0·050	—0·134	—0·893

Canal Marseille. Expt. 7. Sub surface Velocity Observations.

Earthen bed. Width, 19·7 feet. Depth, 4·36 feet. Mean velocity, 2·536 feet. Wind strong down stream. Depth of axis, 0·1 ft. or 0·02 of total depth. Maximum velocity, 3·283 feet.

Vertical plane.	Velocity at following depths below the surface.						
	0·07 ft.	0·30 ft.	1·18 ft.	2·00 ft.	2·99 ft.	3·60 ft.	4·07 ft.
	ft.	ft.	ft.	ft.	ft.	ft.	ft
Mean of 5 central curves	4·039	3·301	3·156	3·074	2·674	2·432	1·647
By formula	3·282	3·280	3·201	3·031	2·699	2·427	2·181
Discrepancy......	+0·757	+0·021	—0·045	+0·043	—0·025	+0·005	—0·534

The result of this comparison of formula and observation is satisfactory, for not only are the curves parabolas with their axes submerged and evidently affected by the wind, but even their degrees of curvature are closely predicted by the equation. To continue the investigation and fully discuss in this manner all the data furnished by MM. Darcy and Bazin relating to the laws governing the action of cohesion, would be extremely interesting, and might probably result in extending and perfecting the expression for the parameter —which for very shallow depths, where its variation is most rapid, is based upon only two observations made by Capt. Boileau—but such an analysis would hardly come within the scope of this paper.

M. Grebenau has confirmed our law for the action of cohesion, both by original observations and by collating older data. He gives a plate which represents these results to the eye in a striking manner, and sustains his conclusion that the law is obvious in all the earlier observations as well as in his own. He accounts for its non-discovery before, by the fact that graphical analysis was not used.

Gen. Warren's unpublished data upon the Upper Mississippi, also confirm our parabolic law; as, indeed, do other recent measurements.

Observations also show that in horizontal planes, as well as vertical, the law of transmission of the resistances experienced at the banks, is parabolic. Indeed, this conclusion logically follows from the foregoing principles, since the cohesion of the different particles to each other must act in the same manner in whatever direction the disrupting force is applied. Unfortunately, however, in horizontal planes the law of transmission is usually obscured by the set of the current, by variations in depth, and by other local agencies. At Columbus, Ky., the entire horizontal curve of the Mississippi was a parabola whose parameter varied precisely in accordance with the laws governing in vertical planes parallel to the current. At other localities, the horizontal curves seemed to be made up of arcs of different parabolas combined in so intricate relations as to defy analysis.

The difficulty which it was foreseen would cause our formula to indicate too large velocities when applied to very small cross sections can now be understood. Equating the expressions for the accelerating and retarding forces, as explained above, and reducing, the following equation results; in which U_o and U_r denote respectively the mean of all the surface and the mean of all the bottom velocities.

$$\frac{a\,s}{p + W} = f\left(\frac{U_o\,W + U_r\,p}{W + p}\right)$$

Now to deduce the *mean velocity* from this equation, it is necessary to introduce for U_o and U_r their equations based upon the vertical and horizontal parabolas indicating the action of cohesion. For the vertical curve this was done in framing our formula; but the complex nature of the horizontal curves eluded research, and we were compelled to use the following empirical expression, in which U_m denotes the grand mean of all the mean velocities in all the different vertical planes parallel to the current.

$$U_m = 0{\cdot}93\ v$$

This expression, (see page 290 Physics and Hydraulics of the Mississippi) accords very well with observations upon natural channels of the size of those upon which our observations were made, but it was clearly perceived that it really involved a variable function of the parameters of the arcs of parabolas of which the horizontal curve is composed; as well as a function, probably nearly constant for rivers, dependent upon the form of cross section and the number and lengths of the arcs of the different parabolas. In other words, theory required that the expression should be written.

$$U_m = A\sqrt{\frac{B\,v}{\sqrt{c + W}}}\,v = A\sqrt{\frac{B}{\sqrt{c + W}}}\,v^{\frac{3}{2}} = A\sqrt{b'}\,v^{\frac{3}{2}}$$

It is evident from the form of this expression,—in view of the necessarily small numerical values of B and C relative to that of W,—that it must be sensibly constant, except for very small values of W. That we were correct in this assumption is shown by the close accordance of our formula with observations upon ordinary natural channels. The little canals of MM. Darcy and Bazin furnish data in which, from the small values of W, the constancy of the numerical value of b' is destroyed; and, in consequence of the manner in which it enters the equation, the formula must indicate too large velocities.

To recapitulate in general terms, b, the function of the depth entering the expression for the parameter of vertical curves, is essentially constant until the depth is reduced to about a dozen feet. These data of MM. Darcy and Bazin indicate the same to be true for the function of the width entering the expression for the parameter of the horizontal curves. It remains, therefore, to consider how to correct the formula to suit very small natural streams, by introducing a known function of the width as a variable.

Making the substitutions and reductions indicated upon page 300 Physics and Hydraulics of the Mississippi, and substituting for 0·93 v the value just given, the general expression for $\frac{a\,s}{p + W}$ on the opposite page, becomes:

$$\frac{a\,s}{p + W} = f\left(A\sqrt{b'}\,v^{\frac{3}{2}} - 0{\cdot}167\sqrt{b\,v}\right)$$

By a process similar to that employed in deducing the form of the function composing the second member of the analogous equation on page 311 Physics and Hydraulics of the Mississippi--determining the value of the constants in the expression for A $\sqrt{b'}$ by a tedious method of approximation applied to the new data for the feeders Grosbois and Chazilly—it would be possible to arrive at a general equation for the mean velocity, applicable to cross sections less than 100 sq. ft. in area, as well as to large rivers. It has not seemed to me advisable to adopt this method at present, partly because the resulting formula would be inconveniently complex, and partly because, as a preliminary step, the equation for b for very shallow depths, say less than 4 or 5 ft., should be carefully studied. The data used in fixing this part of the curve when the formula was framed, were meagre, and it may be that a thorough analysis of the new and more extended sub-surface velocity observations of MM. Darcy and Bazin, would, beside introducing a function dependent upon the nature of the material composing the bed, indicate a slightly increased curvature. A hasty inspection has led me to surmise that the latter would be the case; if so, the effect upon our general equation for v would be to slightly diminish the computed values of that quantity for very small channels (without affecting them for rivers) and would thus reduce the amount of the correction now attributed to the influence of the diminished width. A thorough and laborious analysis of the whole subject for *very small streams* is desirable, pending which, since b' is sensibly a variable only for the smallest channels, it has seemed to me advisable to use a more simple method of introducing the width correction for such cases, by appending as a subtractive term a function of the width and mean velocity analogous in form to the expression for the parameter of horizontal curves.

The most simple and convenient form for such a term, is the following, in which v' denotes the mean velocity as first computed, and u the amount to be subtracted from that velocity to reduce it to the true mean velocity. A and B are constants. The wetted perimeter is used instead of the width, because for this purpose it is essentially the same in value, and is given exactly in the reported observations, while the width is not.

$$u = \frac{A \sqrt{v'}}{B + p}$$

From a careful discussion of the 28 observations of MM. Darcy and Bazin upon the feeders Grosbois and Chazilly, A is found to be

2·4 and B to be 1, making the expression for the reduction in mean velocity resulting from a diminution in width, through its influence upon the parameter of the horizontal curves, become

$$u = \frac{2{\cdot}4 \sqrt{v'}}{1 + p}$$

Assuming for the moment this expression to be correct, it is interesting to roughly compare the relative effects of proportional reductions in depth and width upon the mean velocity, due to the influence such reductions exert upon the parameters of the parabolas which define the law of transmission of resistances through the fluid mass. It will, of course, be borne in mind that the controlling effects of such changes in cross section are taken into account by the expression

$$\frac{a}{p + W}$$

Take, for example, the Mississippi river, 2600 feet wide and 80 feet deep, and flowing with a velocity of 4 feet per second. Reduce the depth to 1 foot, and that part of the loss of velocity due solely to the change of form in the vertical curves will be by our formula about 0·2 ft. If the velocity were 1·5 ft. per second, the corresponding reduction would be about 0·15 ft. Reducing the width in the same proportion, namely to 32 ft., the part of the loss in velocity due solely to the change of form in the horizontal curves, is shown by the above expression to be about 0·15 ft. and 0·08 ft. respectively, for mean velocities of 4 ft. and 1·5 ft. Of course, the numerical values of such reductions vary according to the dimensions of the primitive stream; but that the amount indicated by this expression, deduced from the observations of MM. Darcy and Bazin, accords in general with the results of the study of vertical curves upon the Mississippi, is evident.

The following table exhibits the results obtained by applying the correction u to the indications of our formula for the observations of the last class (area of cross section less than 50 ft.) in the general table. The data in full, and the results of the Darcy-Bazin and Hagen formulæ, are repeated for convenience of comparison.

It will be noticed that the discrepancies of our formula, with the new correction term added, are slightly less than those of the Darcy-Bazin formula for their own data.

Measurements upon Very Small Streams, with Tests of Formulæ.

No.	Stream.	Original.		Cross Section.			Slope.	Observed Mean Velocity.	Discrepancy.		
		No	Series.	Area.	Wetted Perimeter.	Mean Radius.			D. B Formula.	Hagen Formula.	H. A Formula.
				sq ft.	ft.	ft.		ft.	ft.	ft	ft.
1	Feeder Chazilly...	1	37	9·5	9·9	0·96	0·000 792	1·234	−0·062	−0·072	−0 013
2	....	2		14·9	12·3	1·21	0·000 808	1·667	+0·067	+0 193	+0·175
3	....	3		19·4	13·8	1·41	0·000 858	1·815	−0·091	+0·208	+0·127
4	....	4		22·9	14·7	1·56	0·000 842	1·998	−0·060	+0·314	+0·203
5	....	1	38	9·3	9 7	0·96	0·000 957	1·244	−0·187	−0·106	−0·098
6	....	2		14·1	11·9	1·18	0·000 929	1·703	0·060	+0 213	+0·176
7	....	3		18·8	13·3	1·41	0·000 993	1·798	−0·252	+0·152	+0·025
8	....	4		22·2	14·4	1 54	0 000 986	1·959	−0·255	+0·244	+0 121
9	....	1	41	11 3	19·8	1·04	0·000 445	0·962	−0·087	−0·275	−0·163
10	....	2		18·1	13·1	1·38	0·000 450	1 296	−0·091	−0·132	−0 079
11	....	3		22·9	14·6	1·57	0·000 455	1·401	−0 112	−0·125	−0 118
12	....	4		27·2	15 9	1 71	0·000 141	1·510	−0·106	−0·074	−0·087
13	Feeder Grosbois	1	47	11·8	10·8	1·09	0·000 461	0·820	−0·295	−0·455	−0·348
14	....	2		17·2	12·5	1·38	0·000 450	1 326	−0·027	− ·102	−0·012
15	....	3		23·0	14·1	1·63	0·000 179	1·434	−0·172	−0·134	−0·125
16	....	4		26·8	15 7	1·71	0·000 493	1·683	−0·017	+0·070	+0 041
17	....	1	48	10·1	10 2	0 98	0·000 555	0·984	−0·157	−0·262	−0 162
18	....	2		15·4	11 8	1·30	0·000 555	1·480	+0·059	+0 045	+0·091
19	....	3		20 9	13 4	1·56	0·000 525	1·575	−0·047	+0·018	+0·023
20	....	4		25·9	14·1	1·71	0·000 515	1·746	0·000	+0·122	+0 211
21	....	1	49	10·9	11·4	0·96	0·000 250	0·886	+0·155	−0 194	−0·023
22	....	2		17·1	12 9	1·32	0·000 275	1·336	+0 321	+0·050	+0·175
23	....	3		24·2	15·5	1·57	0·000 246	1·362	+0·245	−0·015	+0·083
24	....	4		30·8	17·3	1·78	0·000 275	1·167	+0·148	−0·027	+0·060
25	....	1	50	10·8	11·3	1·05	0·000 310	0·817	−0·065	−0·353	−0·205
26	....	2		18·0	12·7	1·42	0·000 290	1·260	+0·051	−0·086	+0·034
27	....	3		25·4	15·4	1·69	0·000 330	1·296	−0·092	−0·204	−0·033
28	....	4		32·0	17·3	1·85	0·000 330	1·411	−0·085	−0 157	−0·138
80	River Schwarza...	1		46 7	58·3	0·80	0·009 000	2·728	−1·186	+0 737	−0·106
82	Hockenbach, I–II			10·5	12·0	0·87	0 000 778 3	1·440	+0·263	+0·198	+0 201
83	" II–III			10·3	11·8	0·88	0·000 796 6	1·463	+0·259	+0·209	+0·252
84	Speyerbach.........			30 2	19·7	1·54	0 000 466 6	1·814	−0·297	+0·300	+0·201
85	Huebengraben.....			3·8	6 4	0·59	0·001 300 0	1 424	+0·360	+0 310	+0·479
	Total..........	33						48 139	5·731	6·156	4·388

In fine, then, we have the following table exhibiting for natural channels the absolute and relative accuracy of the Darcy Bazin and Hagen formulæ, and of our Mississippi formula, including the new term for width correction.

This table exhibits in a striking manner the extended applicability of the Mississippi formula. It is clear that in order to truly represent the flow of water, every possible cause of variation must be taken into account. In our formula this has been scrupulously done. The effect of the slope, the area of cross section, the perimeter and the width upon the velocity of the exterior layer of the fluid; the effect of variations in velocity and in depth, and now—thanks to the new

Final Analysis of the Grand Table of River Data.

Areas of Cross Section, varying between	No. of Obs.	Sum of observed Velocities.	Sum of computed Velocities.			Sum of Discrepancies.			Percentage of Discrepancies.		
			D. B. Formula.	Hagen Formula.	H. A. Formula.	D. B. Formula.	Hagen Formula.	H. A. Formula.	D. B. Formula.	Hagen Formula.	H. A. Formula.
Sq. ft.		ft.	ft.	ft.	ft.	ft.	ft	ft.			
200 000 and 10 000	19	89·914	80·709	92·058	93·405	22 123	8 124	5·451	24·6	9·1	6·1
10 000 and 1 000	35	116·880	120·266	112·419	121·012	14·108	18 447	11 438	12·1	15·8	9·7
1 000 and 50	11	27·250	29 171	22·199	26·743	3·899	5·497	2 061	14·3	20·2	7·5
Less than 50	33	48·139	49·814	47·529	47·168	5·731	6·156	4·388	11·9	12·8	9 1
Total,	98	282·183	279·960	274·205	288·328	45·861	38·224	23·338	16·3	13·5	8·2

and valuable experiments—in width also, upon the transmission of these exterior resistances through the fluid mass, have all been carefully considered. It is gratifying to find from this large table of data, less than one-third *of which was available in studying the subject and in framing the equations*, that the investigation has resulted in a river formula which for slopes not exceeding 0·009 reduces the average percentage of error in computed mean velocity to about eight per cent., or nearly to the limits of error in careful actual measurement;*

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* See second edition of the Lowell Hydraulic Experiments, by Mr. James B. Francis, Civil Engineer in Charge. It is a standard authority, giving the results of elaborate experiments, both with hydraulic motors, and in gauging the flow of water over weirs, through short open rectangular canals and through submerged orifices and diverging tubes. The gauging of the open canals was done by floats, consisting of cylindrical rods so ballasted as to remain vertical and extending from the surface nearly to the bottom They were well distributed across the canals, which were from 8 to 9 feet deep and either about 13 or 26 feet wide. All the details of observation and computation were so arranged as to secure the highest attainable accuracy. The computed results, corrected by an original formula for the depth not covered by the rod, were checked by an exact weir measurement, and the liability of the method to error was thus closely determined. The following extracts give useful information in this connection: "The observed velocity at the same part of the section is constantly varying; this is not due, in any sensible degree, to errors of observation, but to actual changes in the velocity, due to the unstable condition of the current" From seven experiments made in calm weather, Mr. Francis infers "that any single measurement is liable to be erroneous to the amount of one per cent. or perhaps rather more." From seven experiments made in a strong wind, he decides "that the irregularities in the results of the measurements were much greater when the wind was blowing strongly than when it was calm, or nearly so. The extreme variation in the seven experiments is nearly five per cent." The liability to error in gauging rivers must of course considerably exceed these limits.

and this, too, whether the stream is a river like the Mississippi or a canal feeder—always provided that *its bed is of earth, and of a roughness of surface and regularity of section usual in straight portions of rivers of corresponding slope.*

MM. Darcy and Bazin possessed no data upon very large rivers, nor upon those whose slopes ranged through extended limits. For this reason they were able to represent by a simple "formula of interpolation" the material at hand. Expressed in English feet, it can be put into the following convenient form for use. Had more extended data been available, it would doubtless have undergone extensive modification—especially in relation to the slope, which for natural channels, at least, should not enter to a higher degree than the fourth root. It is probable that for artificial beds, a higher power may correctly represent observation; but in natural channels the resistances due to inequalities of cross section rapidly increase with the mean velocity, and accordingly we find that slight variations in slope produce great effects upon the discharge when the slope is very small, and have little influence when it is great. The law of change exacts a small fractional exponent for this variable.

$$v = r \sqrt{\frac{1000\,s}{0{\cdot}08534\,r + 0{\cdot}35}}$$

M. Hagen had access to much more of the data in the foregoing table than did either M. Bazin or ourselves; but groping for an empirical expression rather than seeking a formula grounded upon scientific principles, he has failed to frame one of general applicability. His expression is:

$$v = 4{\cdot}39 \sqrt{r} \sqrt[6]{s}$$

To each of these formulæ, the language used by M. Bazin respecting an equation of M. Darcy is strictly applicable: "It represents very well the results of the experiments from which it has been deduced; but, like every empirical formula, it cannot be employed with certainty beyond the limits within which it has been obtained." For general application, they are evidently too simple to prove exact, since many causes of variation in flow are not represented.

To the three classes into which MM. Darcy and Bazin divide *artificial* channels, their formulæ—differing only in the numerical values of the constants from that for natural channels given above—seem to apply. It would be interesting to determine whether still closer accordances with observation might not be obtained, by employing the same analysis with these classes of channels as was used in deducing our river formula. For this purpose, it would only be necessary to follow the rigorous method above indicated. Since artificial streams are necessarily very small, it would be requisite first to study, in the manner already explained, the numerical values of the constants in the expressions for b and b'. Possibly a function dependent upon the nature of the bed, introduced into the equations for these variables might render a single formula applicable to all classes of uncovered artificial channels.

Our formula is too complex for convenience in computation, when applied to small streams; and I have therefore thought it desirable to prepare the appended table to facilitate its use. The following equations—of which the first represents the formula in full, and the second as simplified for use with the table—render it easy to understand the proposed application. For streams larger than 50 feet in cross section, the term involving M′ may be dropped; and for large rivers exceeding a dozen or twenty feet in mean radius, M—but not $\sqrt{M}$—may be neglected.

The symbols have the following significations; all expressed in English feet:

v = mean velocity.

v' = value of first term in the expression for v.

a = area of cross section.

p = wetted perimeter.

W = width.

r = mean radius or $\frac{a}{p}$

s = sine of slope of water surface, corrected for bends. Its numerical value is found by dividing by the total distance between the level stations, measured on the middle line of the channel, the total fall between them, after subtracting the value of h' in the following formula for bend effect, in which N represents the number of angles, 30° each, of the mid-channel line. $h' = \frac{v^2 \text{ N} \sin^2 30°}{194}$. Of course, the method of successive approximation must be used in finding the value of v in this formula.

b = function of depth entering expression for sub-surface curves, or $\frac{1{\cdot}69}{\sqrt{r+1{\cdot}5}}$

$$v=\left(\sqrt{0{\cdot}0081\,b+\left(\frac{225\,a\sqrt{s}}{p+W}\right)^{\frac{1}{2}}}-0{\cdot}09\sqrt{b}\right)^2-\frac{2{\cdot}4\sqrt{v'}}{1+p}$$

$$v=\left(\sqrt{M+\left(\frac{225\,a\sqrt{s}}{p+W}\right)^{\frac{1}{2}}}-\sqrt{M}\right)^2-M'\sqrt{v'}$$

If it be desired to determine any element other than the mean velocity, for a very small stream less than 50 sq. ft. in cross section, the new subtractive term containing M′ should be used in connection with the formulæ given on pages 313, 314, Vol. XLV, and a method of computation by successive approximations must be employed.

Table to Facilitate the Application of the Humphreys-Abbot Formula for Mean Velocity.

r	M	$\sqrt{M}$	p	M′	Log. M′
1	0·0087	0·0930	5	0·400	9·602060
2	0·0073	0·0855	6	0·343	9·535294
3	0·0065	0·0803	7	0·300	9·477121
4	0·0058	0·0764	8	0·267	9·426511
5	0·0054	0·0733	9	0·240	9·380211
6	0·0050	0·0707	10	0·218	9·338456
7	0·0047	0·0685	12	0·185	9·267172
8	0·0044	0·0666	14	0·160	9·204120
9	0·0042	0·0649	16	0·141	9·149219
10	0·0040	0·0634	18	0·126	9·100371
12	0·0037	0·0610	20	0·114	9·056905
14	0·0035	0·0590	22	0·104	9·017033
16	0·0033	0·0573	24	0·096	8·982271
18	0·0031	0·0558	26	0·089	8·949390
20	0·0029	0·0544	28	0·083	8·919078
30	0·0024	0·0494	30	0·078	8·892095
50	0·0019	0·0437	50	0·047	8·672098
100	0·0013	0·0369	100	0·024	8·380211

Chemistry, Physics, Technology, etc.

DECAY AND PRESERVATION OF TIMBER.

I. *Theory of decay in wood.*—It is theoretically claimed that the principal inherent action producing decay in wood are:

Firstly. The decomposition of the albumen contained in the sap part, and from this decomposition results a poison which being in juxtaposition with the heart part, induces speedy decay in it.

Secondly. Slow oxidation or spontaneous combustion, which may go on in both the sap and the heart parts, more particularly in the latter.

Thirdly. It is added by some to the first two postulates, that "air and water are essential to the decay of wood."

II. *Experience in respect to wood, untreated, and treated with antiseptics.*—While I am not disposed to doubt the first two points of theory just quoted, I am nevertheless constrained to deny the third, and to believe on the contrary that air and water—especially fresh water—do essentially preserve untreated timber from decay. The stubborn fact of green and seasoned timber for constructions being put under water and there remaining for a century, subject also to air, which always exists more or less in agitated water, without the slightest sign of decay and then found as strong as ever, is sufficient to overthrow the third point of this theory. And but for the sea-worms and barnacles, the same experience holds for untreated timber under sea or salt water.

I have known oak and pine beams, encased in solid brick masonry where hardly any air or moisture could reach, perfectly rotten after eleven years of such imprisonment.

Nor can it be maintained that all kinds of untreated wood exposed to soil, air and water will very speedily decay. The speediness of decay of timber thus exposed will depend upon the kind of wood, the particular acids or salts in the soil, the climate where the timber is to be used, and the thickness of the sticks. To illustrate this, it is only necessary to adduce a few facts which have come under my own observation, also, some well authenticated circumstances coming under the observation of other engineers of constructions.

In houses of the old dilapidated town of Chagres, lignumvitæ mudsills were found, after lying seventy-two years upon the ground, perfectly sound. This induced the engineers of the Panama R. R. Co. to replace their first ties, which were of the very best Georgia pine, and which lasted not to exceed three years, with lignumvitæ brought from Darien, at a cost (in 1855) of $1.00 per tie. The same Georgia pine taken to a northern climate would have lasted as railroad ties seven years, at least, before requiring renewal.

Red cedar heart in its natural state as fence posts and mudsills has lasted fifty years in the clay and gravelly loam in northern climates without appreciable decay, but in strong lime soil it yields in less time; while white or yellow cedar will last only from fifteen to twenty years before it will become decayed in a similar exposure and soil.

In the rich bottom lands of Wisconsin, I saw the original massive white oak trunks exhumed as it were from beneath the mucky ground, where they had been upturned by an ancient tornado, and timber made from them in 1842; the wood was then perfectly sound after an age of centuries, and the timber made from them, used in a construction under cover, is at the present time as sound as ever. Those oaks must, judging from the age of the trees succeeding them and growing among and over their prostrate bodies, have lain there for centuries; and yet in the very same neighborhood the same kind of oak apparently cut from the living trees, lasted as fence posts in a limy clay soil only ten years, untreated.

The untreated "redwood" of California, in contact with soil from volcanic debris, I found, on testing its durability, quite as lasting as our red cedar, though it is by no means the same kind of wood. It is weak and brittle; neither is it the same kind of wood as the "mammoth trees" of that State.

I have found our northern red cedar, treated with the old Kyan process, an infusion of corrosive sublimate, after twenty-two years' exposure lying on a slope of strong limy soil, to have gone to decay, especially the lower ends of the sticks, and kyanized white oak of Michigan, resting upon the same kind of dirt, dozed and rotted twenty years after the treatment.

Chestnut railroad ties grown upon the barrens of Maryland, kyanized and laid upon a limy soil some miles north of Baltimore in 1838, I saw tested eleven years afterwards and then perfectly sound, and more solid than when laid; while those of the same kind of wood, untreated, but laid at the same time in the same kind of soil and exposure with the treated ones, lasted only seven years before they required renewal.

This experiment of kyanizing timber was the first, I believe, ever practiced in our country. Ties enough were treated for one mile of track, costing twelve and a half cents per cubic foot of timber. The process, however, was so unhealthy, salivating all the men, it had to be abandoned It would be worth while to ascertain if those kyanized ties are yet sound. At that time the untreated ties cost only fourteen to sixteen cents.

The original growth of white soft pine of New England, in fence boards untreated and not touching the ground, has been known, after an exposure of more than fifty years, free from all signs of decay, while heavy sticks of timber of the same wood and similar exposure, were found much decayed in a shorter period. White spruce and red hemlock of that part of our country I found, on examination, untreated, would only last, the former eleven years, and the latter nine years, while white hemlock is more durable than either.

In my experience, going back to 1839, in respect to harbor pier works on our fresh water lakes, I have found all kinds of timber grown in the vicinity of these waters, and used in the constructions after having laid forty years under water, as sound and strong as when put in fresh from the stump; and I have not the slightest doubt of their lasting, so far as decay is concerned, ten times forty years longer. And untreated white oak and white elm piles, which must have been driven at least forty years, I have found perfectly sound all below and for one or two feet above water, their tops being injured only by abrasion. In these waters there is no need of treating by any antiseptic the timbers to be placed under water.

But for all the horizontal-side, end and tie timbers above the first foot above water, the experience is quite different. As a general rule, I have found these timbers to show decay in seven years after being laid without treatment; and yet many have lain from twelve to fifteen years; but then they have become so rotten as to be blown away by the winds or torn off by the waves. Without treatment, therefore, by some antiseptic we cannot rely upon the timber in these superstructures lasting more than seven years without need of renewal.

In the pier superstructures, we have used chiefly white and hard or red pine and white oak. The vast amount of beautifully shaped timber for the sizes we need, but deemed as too inferior in quality for these superstructures, growing, however, in the vicinity of the lake shores, such as hemlock, white cedar, bass, fir, white and black ash, hickory, white elm, beech, sycamore, etc., etc., are utterly ignored.

An antiseptic that would materially, say double or triple, the period of decay in these would enable us to bring them into use, at a cost for the untreated timber considerably below that of pine and oak.

The ancient Egyptians must have known of antiseptics for preserving wood. Their old wooden coffins, after 2,000 years, have been brought to light; and a gentleman of much experience in the causes of decay and means of "preservation of wood," has informed me, he "has seen several of these split to pieces, and that the wood (sycamore) was perfectly sound and strong; the wood seemed to have been impregnated with a bituminous substance. The coffins were 'dug outs' from solid blocks of the wood, leaving a hole in the top to insert the corpse, and having a lid carved and ingeniously fitted to enclose the aperture." Now sycamore, as we know it, untreated, is not a very lasting wood. Whether the lost art is to be recovered by the use of modern antiseptics remains to be seen by future generations.

Worms in Wood on Land and in the Open Air.—There is a destructive attack by these upon wood of the trees which have been cut into logs, out of which timber and lumber are to be manufactured at the mill.

The trees are generally felled and immediately cut into lengths suitable for these logs in the winter, and either hauled to the mill during the same winter or rafted to it early in the spring and sawed during the same spring and succeeding summer. In this way the eating by the worm is in a great measure avoided. But if the logs of almost any kind of wood are allowed to lie over the summer on the ground, they almost invariably become eaten, unless they are "drossed," which means, to hew off their bark. Peeling the bark of the hemlock in June for tanneries, will prevent the worm in this kind of wood.

If the season, however, is very wet and cold, logs with their bark on are less liable to attack where they lie over; and if they are "boomed," or put into a "log bay" of fresh water, they are preserved from this kind of worm, unless the eggs of the larva are laid in the logs before they can be put into the water, in which case the larva are known to develop into the living worm in six months after sawing and sticking up the stuff, which, though apparently free from the worm when piled, soon becomes greatly injured, as many a pile of supposed valuable timber has shown.

When a thrifty tree, however, is overturned by the roots and, after dying, cut into saw-logs or hewn, no worms will be found in the wood.

Some of the very best lumber comes from wind-falls after the trees have been dead for years, taking care, however, not to sever the rooty mass from the trunks while green. These facts led to the explanation of the manner in which these worms are produced in saw-logs and green timber recently felled by the axe. A small insect easily penetrates by the ends of the green log along through its whole length in the palatable juices between the dark and sap wood and deposits her eggs, which very rapidly develop into eating worms. No doubt there are various kinds and sizes of these preying upon wood, and among which may be classed the ants, which are so destructive to wood in tropical climates.

A windfall, with its up-turned roots having earth attached, affords no access to the insect: and when the green logs are "drossed," there is no bark shelter for the insect which dreads the water so much that it will not enter the logs after an immersion in fresh water.

It seems to me that if the lumber manufacturer has the ill luck of being compelled to allow the green logs to lie over on the ground, the besmearing of the ends with some cheap bad smelling paint might prevent the access of the insect.

Worms in Wood under Sea-water.—These, I have observed, on our sea-coasts, seldom work upon piles and dock-facing timbers, except in those parts standing between half ebb and half flood tides; in the space between these two planes, however, their operations are indeed wonderful and dreadfully destructive. On some of the European coasts, I think they range in their attacks from extreme low to nearly high tide.

It is not very many years since it was believed these worms could only exist in the tropical climates, and that they were only known in cold climates by being brought in vessel bottoms. But this was an illusion which experience has since dispelled.

As far east as Castine Harbor, Me., they began destroying piles and other dock timbers of the best white oak, and so effectually did their work that renewals had to be made. It is believed they were introduced there from old worm-eaten vessels coming home and lying to the docks until the vessels no longer afforded substance for boring, then the worms forsook, and resorted to the piles and dock timbers. No oak has for years been used there for the renewals. Yellow pine is used, and as long as the resin remains in the wood, it is comparatively free from the worm; but after a few years, the resin becomes washed out, then the worms commence the havoc in good earnest.

In various places on our Atlantic coast from Maine to Mexico, and on our own Pacific coast, this annoying and costly evil exists. There, I have observed, no vessel or wood structure, except as high up as about where the fresh water and the tide water meet, is safe from this evil. The remedy of covering the exposed parts with the sheet copper is only effectual until the sheathing becomes punctured, torn, or abraded off, then the worms immediately enter.

In the bay of San Francisco, the worms are very active and produce great havoc. They bore deep into the piles and dock timbers, leaving hardly any part within their range unperforated, but the tubular track of one never pierces across the tube bored by another worm. Their instinct teaches them scrupulous respect for each other's way. In a period of less than four years they will destroy the piles. And there are worms that wield their mandibles with such extraordinary power as even to bore into solid rock.

In the lower part of the Sacramento river, just above where it enters Suisune Bay, the banks at low tide expose all along for one or two miles innumerable hard compact sand-boulder rocks. In carrying a military survey along these banks, I observed in hundreds of the rocks deep tubular holes of from one half to three-eighths inch in diameter, running straight in, some to the depth of eighteen inches. Every hole was lined with a perfect coating of beautiful white enamel as hard as glass. At the bottom of each hole there was invariably a worm found, who had bored for himself a habitation into the rock. These extraordinary mandibular worms, if not the same kind, are about the same size, I judged, as the smaller kind of salt water borers called *limnoria*.

The, piles used in the San Francisco waters, are chiefly Oregon spruce and Oregon pine. An antiseptic that will preserve wood there will not fail to be favorably received.

I submit a tabular statement, A, of results of experiments in "creosoting" wood in foreign countries for preventing attacks of these worms, by which it will be seen at a glance how efficacious this has proved thus far. How much longer in the future it will hold their sharp mandibles in check, can only be known by future observations, which I trust will be made by those civil engineers from whose reports I have made up the table or by those succeeding to their places.

APPARATUS USED IN CREOSOTING TIMBER AT ST. CLAIR FLATS, MICH.

PATENTS OF SEELY & PELTON.

Accompanying Report of Genl. T. J. CRAM, U.S. Corps of Engineers, to the Chief of Engineers, U.S.A.

1871

Fig. 3.

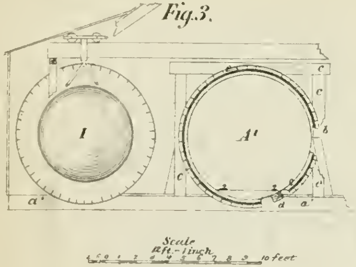
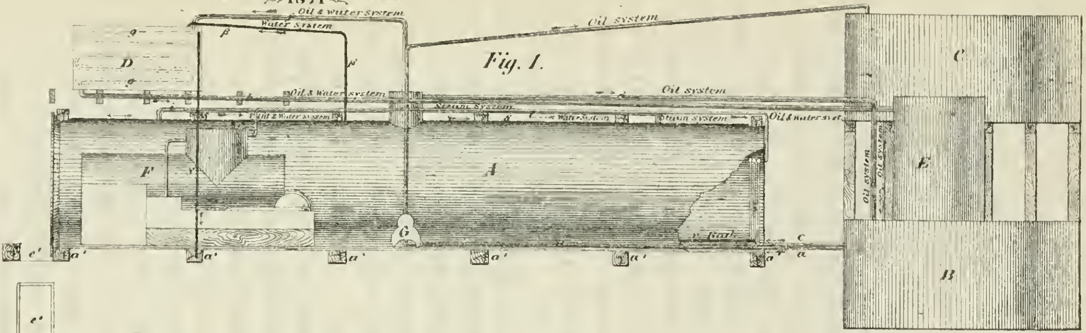


Fig. 1.



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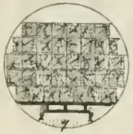

Fig. 2.

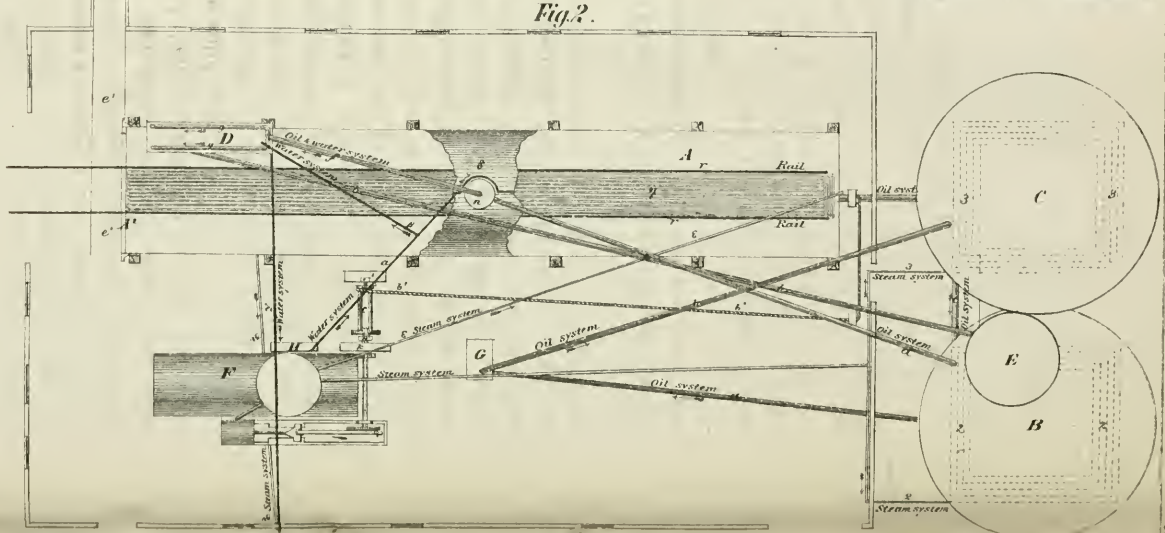

Fig. 5.

Fig. 6.

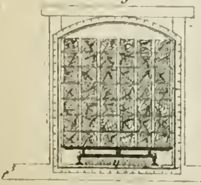

TABLE A.

Results of Creosoting Wood in Foreign Countries, to prevent attacks from sea-worms, compared with results pertaining to the same wood, untreated.

Places of Experiment and Authority.	Kind of wood creosoted.	Period of years in use after creosoting.	Condition at expiration of that period.	Period the wood would have lasted uncreosoted before destruction by worms.
Ostend Harbor. L. Crepin, *Engineer, &c.*	Baltic Fir.	7	No attack. Sound.	2
Leith Pier and Harbor. Thomas Maclane, *C. E.*	Not Stated.	12	No attack. Sound.	3½
Docks at Monk-Wearmouth. A. Forestier, *Engineer.*	Yellow Pine.	20	No attack. Sound.	Not Stated.
Teignmouth. Mr. Brunel, *Engineer.*	Not Stated.	7	No attack. Sound.	Not Stated.
Grimsby Dock Adam Smith, *Engineer.*	Not Stated.	7	No attack. Sound.	3
Portland Breakwater. John Coode, *Engineer.*	Not Stated.	4	No attack. Sound.	3

At Leith Pier, the piles were dosed by using ten pounds of the oil, the cross ties and stringers seven pounds, and planks six pounds per cubic foot.

In France, Belgium and Holland, I learn, that from sixteen to twenty-six pounds of the oil, per cubic foot of the timber, was used for marine purposes formerly. Mr. George Shepard Page, who has extensively examined marine works in Europe, reports six to nine pounds, as now used to the cubic foot in sea-constructions, and says, "in no case has properly creosoted wood, employed to prevent the worm, failed to give complete satisfaction."

TABLE B.

Results of Creosoting Wood in Foreign Countries for Props in Collieries, compared with the duration without treatment.

Place of Experiment and Authority.	Kind of Wood Creosoted and Used.	Period of Years in Use after Creosoting.	Condition at expiration of that period.	Period the Wood lasts without Creosoting.
South Durham Colliery. Adam Hackworth, *Overseer.*	Not Stated.	15	Perfectly Sound.	¾ of a Year.
Tanfield Moor Colliery, James Joicy & Co.	Larch.	7	Perfectly Sound.	1½ Year only.
Mickley Colliery. Matthew Liddell.	Larch. Scotch Fir.	14 14	Perfectly Sound do. do.	6 Years. 4 Years.

The larch here spoken of is, I believe, similar to our American bald spruce or tamarack.

TABLE C.

Results of Creosoting Wood for Railroad Ties in Foreign Countries, compared with the duration of the same wood Uncreosoted, for Ties.

NAME OF RAILWAY AND AUTHORITY FOR THE EXPERIMENT.	Kind of Wood Creosoted and used for the ties and longitudinal timbers.	Period of Years in use after creosoting.	Condition at expiration of that Period.	Period of duration for the same purpose, uncreosoted.
MANCHESTER & CREWE RAILROAD. *Building News*— July 5th, 1870.	American White Fir.	32	Perfectly Sound.	Not Stated.
COLOGNE & MINDEN RAILROAD. G. Freme, *Inspector*.	Not Stated.	12	Perfectly Sound.	4
INDIA RAILROADS. Mr. Burt.	Not Stated.	20	Perfectly Sound.	Not Stated.
STOCKTON & DARLINGTON. Thomas Summerson, *Inspector*.	Yellow Pine.	26	Perfectly Sound.	6½
YORKSHIRE & LANCASHIRE RAILROAD. R. J. Badge.	Not Stated.	24	Perfectly Sound.	Not Stated.
MIDLAND & GREAT WESTERN RAILROAD. James Price.	Red Baltic Fir.	9	Perfectly Sound.	Not Stated.
GREAT EASTERN R. R. Samuel Dawson, *Sup't*.	Scotch Fir.	16	Perfectly Sound.	Not Stated
BELGIUM RAILROADS. Minister of Public Works.	Red Pine, Oak, Beech.	19	Perfectly Sound.	Not Stated.
AUSTRIAN, FRENCH, PRUSSIAN AND RUSSIAN RAILROADS. George Shepard Page.	Baltic Fir.	20	Perfectly Sound.	4

It is to be observed, that at the expirations of the periods expressed in the third column of A, B, C, the timber which was treated is reported perfectly sound; there is no evidence showing how much longer it will last; and I can find no evidence of any which has been creosoted having yet decayed, or having been attacked by worms.

Among the quoted authorities, I gather from those who have given recent attention to the subject, that from seven to nine pounds of creosote oil per cubic foot of timber used for railroads and other purposes on land, is the proper dose. It is to be regretted that in none of the foregoing experiments, the cost of creosoting per cubic foot, the original cost of the untreated timber, nor the cost of the labor of construction per cubic foot, is given. The only data I can obtain from foreign reports on either of these points, is from one on the Dublin and Drogheda R. R.; and I deduce from this data, that the creosoting of the ties costs six cents per cubic foot of timber with seven pounds of "crude" oil per cubic foot. Without all the items just mentioned, it is impossible to solve the problem of the measure of the economy of creosoting in foreign countries.

Mr. Page, whose report bears date 28th May, 1870, made the subject of a specialty recently in European countries. He says, that "the creosoted timber for railroad constructions has not yet failed from perfect soundness. * * * Wood for marine constructions, railroad constructions, fences, telegraph and hop poles, and for uses in coal and iron mines, is almost universally creosoted; and that treated timber is the rule; and untreated timber the exception. * * Another effect is observed; iron spikes, nails, bolts, etc., inserted in creosoted wood are protected effectually from rust. * * * And crude creosote oil is almost universally used in the process all over Europe."

(To be continued.)

CHEMICAL AND SANITARY REPORT UPON THE PASSAIC RIVER.

Made to the Board of Public Works of Jersey City.

By Professor Henry Wurtz.

(Abstract, made and communicated to this Journal, by the Author.)

Hoboken, *March* 1*st*, 1873.

Gentlemen,—I have been charged by your Honorable Board with the investigation of the waters of the Passaic, with a view to determine the sanitary questions regarding contamination by sewage and other causes.

All the analytical results herein reported were obtained by the personal labor of the undersigned.

Collection of the Samples for Analysis.—At the outset of the investigation, and on his first visit to your Pumping Works at Belleville, your reporter recognized a source of contamination to the stream which has hitherto been strangely overlooked. It seems incredible that it should be pointed out for the first time here; but, in a sanitary view, it clearly involves the most important questions connected with this stream, and its relations to the rapidly increasing town populations that look thereto for their supply of a necessary of life.

The source of contamination referred to is the flow into your pumps, during rising tides at least, of water which must have received the drainage of the populous city of Newark.

Samples were therefore so collected at Belleville as to enable this new question—regarded as the most important one that has arisen—to be tested analytically; namely, by taking the water at extreme high tide, to represent the maximum of contamination from Newark; as well as at extreme low tide, to represent water contaminated only with matters brought down by the river itself and its affluents above Belleville. An additional sample was taken from the Receiving Reservoir.

It providentially happened that it was possible to procure these samples after an interval of dry atmosphere, of at least eight days (October the 10th, 1872, being the date); thus giving us the important assurance of absence of dilution of the river with rain. Since then there has been no occasion equally favorable: the incessant and almost unexampled alternations of rains, snows and thaws, having kept up in the river a continual condition, more or less, of flood. Samples were afterwards obtained from above the Passaic Falls, from the discharge of two of the main sewers of Paterson, and from the river itself below the discharge of all the sewers of importance, off the Straight Street Bridge, Paterson.

In connection with the sewers, other instructions received from your Honorable Board were, as far as practicable, carried out, relating to inquiries into sources of possible contamination of the sewage waters by mineral and metallic matters, from the different dye works and factories.

The samples were sealed securely, with pure paraffin, at the water works (in the presence of your Chief Engineer, Mr. Culver), and after being packed in an inverted position, were transported to the laboratory of the writer in Hoboken.

Preliminary Preparation of the Samples.—The bottles were placed, without unsealing, in a light room without fire, which, because surrounded by other rooms constantly warmed, remained above freezing even during the intensity of the past winter. The primary object was to obtain such *sediments* as might deposit, including possible products of germination and growth of vegetable spores. In about one month (November 14th), the samples of water, having then become perfectly limpid, though of a pale brownish tint, were carefully pipetted off from the sediments, the latter collected, dried at an extremely gentle heat, weighed, and reserved for examination as below.

The Methods of Analysis.—The older methods of analysis of potable waters, by which it has been customary to determine with great precision the actual quantities and relative proportions, per stated volume, of all the different acids and bases belonging to the purely "inorganic" constituents, have, within a decade past, fallen into disrepute and even desuetude among some chemists who have been active in the advancement of sanitary chemistry; and a far greater importance now attaches, among these, to the so-called "organic" constituents, or rather those assumed to be peculiarly of organic origin. This later school of chemists and sanitarians has in many cases abandoned the practice of determining anything regarding the solid so-called "mineral constituents" more than their simple sum total, after expelling all volatile matter.*

There is, on the other hand, another school of water-analysts, which adheres to older ideas, and, as the writer believes, exaggerates much the difficulties and uncertainties its adherents attach to most of the more recent methods of detecting and determining constituents present in quantities too small to be weighed—a class of constituents comprising many of the products of putrefaction and decay. This school goes so far in the other direction, as to reject the modern "microchemical" methods, as of no practical value.

From this conclusion, and from the general views of both the schools of chemists referred to, the present writer's own experience forces him to dissent; and, in brief, his own belief rests on the middle ground between these two schools; and, in this investigation, he has deemed it essential to apply, as thoroughly as possible, *both* the older and newer schemes of analysis.

Special Observations on Methods.—The residues left by all the samples of water on evaporation in white porcelain, were of an orange buff, approaching to salmon-color, while those left in platinum dishes were gray in color; and all, on heating, turned black, with a strong "peaty" odor, or at least an odor recalling strongly that of peat smoke. This odor, however, is of little value in itself as an indication of the character of the volatile matter present; but subsequent tests proved the presence of one or more of the peaty acids. The incineration was very difficult, more like that of animal matters; and at the point of temperature required to form a white ash, a slight fume was often seen, though too slight to allow its character to be determined. The ash was nearly white, and effervesced slightly with acids, dissolving in muriatic with a distinctly yellow color, indicative of iron.

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*The highly valuable manual on Water-Analysis, by Wanklyn and Chapman, is an example of this, and I fear has done much harm in this direction.

In addition to the samples from Belleville, it was thought important to take the opportunity to obtain the *average* composition of the water for the winter months, just as delivered and used by consumers, sediment and all, from the service pipes in Hoboken. In one case, during twenty days, as much as twenty quarts of the water were concentrated in a platinum dish on a water-bath, the object in this particular case, as well as in one other, having been to determine the ammonia, a drop of sulphuric acid being therefore added at the outset. It is to be remembered that these results on the hydrant water (reported in the fourth columns of the two tables of analyses given below), relate to an unusual winter period, during which the stream was more or less in continual flood.

Within a few years some European analysts have been active in devising new methods of discovering and determining substances which, though often occurring in waters in proportions justly termed microchemical, are nevertheless widely believed now to be of vital importance in a hygienic view.

It appears appropriate and requisite that a few specific though brief paragraphs (which may be more especially interesting, nevertheless, to readers of chemical attainments) should be given to an enumeration at least of the following methods, which were submitted to preliminary examination, and some of which were since made good use of in this research.

The Forchhammer-Condy Permanganate method: with the modifications recommended by Angus Smith, in whose high opinions of the real value of this method, when used understandingly, the writer must largely concur, though he has spent comparatively little time in actual work with it.

The Nessler-Hadow method for ammonia; which, as all chemists now familiarly know, is beyond all price or appreciation, in all chemical analysis, that for sanitary purposes included. To illustrate the extraordinary value of this Nessler-Hadow micro-chemical method, and the enormous stride in advance marked by it, it may here be added that in the evaporation before referred to, of twenty quarts of hydrant water with acid, occupying twenty days, an attempt made to determine ammonia in the residuum, by common alkalimetry, failed altogether. In another parallel experiment, however, involving considerably less time and material, no less than five well-concurrent determinations were made upon the result of distillation with alkali, and three times as many more might have been had. The average figure arrived at is given below—0·005 grain of ammonia per gallon. The failure of the ordinary volumetric methods is here clear enough when we consider that the whole five gallons concentrated contained but one fortieth of a grain of ammonia.

The method for nitrogen acids, founded on reduction to ammonia by a metal. and then the Nessler-Hadow method. Schulze's improvement of using metallic aluminum in alkaline solutions, was found valuable; but the writer has found it far preferable to use, in addition, clipped iron wire, which, while hastening the operation by voltaic action, also subsequently prevents explosive ebullition, and bursting of the retorts. [It may convey to your Honorable Board some idea of *one* of the difficulties of this kind of investigation, to add that each repetition of the determinations of nitric acid here reported, and they were many, required alone at least one day of hard and anxious work and watching, and that before the discovery of the above safeguard, a dangerous explosion, involving damage to property, had occurred.]

The volumetric method for the determination of chlorine, with standard solution of silver and chromate of potash, which has been so highly lauded by some chemists, failed altogether in the hands of the writer, and he had to abandon it.

The Alkaline Permanganate method, for "albumenoids" or Proteine bodies of Wanklyn and Chapman. This method, which is less understood, probably, than any of the others mentioned, has been tested with some care; at first with the unsatisfactory results reported by some other chemists, and at last with some degree of satisfaction. Details cannot be entered into here. It is certain that W. and C. proved the existence of some form of nitrogenous matter in potable waters (previously freed from ammonia), which is convertible into additional ammonia (at least in part) by distillation with their new reagent. They also show similar results with albuminous matters, and with the usual immediate products of their metamorphoses, and it is hard to see what *other* substances could get into fluviatile and many other waters, that could give ammonia in this way. It is on these grounds that the writer has provisionally accepted their views and their methods, and put the results into his tables of analytical results. As Dr. Angus Smith prefers the term proteine to albumen, in this case, it has been used here also. As the rule of Wanklyn and Chapman is to consider ammonia thus found to represent ten times as much "albumenoid," the figures in the table stand for but one tenth as much ammonia.

New Tests of Oxygenation and Rate of Aeration.—The writer has the satisfaction to announce here that, in the progress of this work, he has found new and valuable microchemical tests for potable waters, as to both the existing degree of aeration (or impregnation with free oxygen) and the rate of absorption of aerial oxygen; which he believes will be of especial value in determining the questions that have arisen regarding the Passaic water. Eminent chemists and sanitarians are agreed upon the important bearing of this ingredient (free oxygen) in potable waters. It has been considered as furnishing a measure of the freedom from liability to undergo fermentation or putrefaction: and it will scarce be denied by any that the most highly aerated water is, *ceteris paribus*, the safest. Oxygen is a consumer and destroyer, and in water destroys the enemies to human life therein. Indeed, it is too often the destroyer of human life itself, but with that we have now nothing to do. Streams flow through an atmosphere containing one-fifth of oxygen, but their precise actual contents, and their relative tendency to absorb, and their actual absorption of this agent (which latter is regarded as the measure of their ability to purify themselves), have heretofore been little more than matters of pure guesswork or conjecture. A reasonable hope may now be held that all this will soon be changed. Two or three of the curious and unexpected results of this new method may be mentioned.

Sewage which smells offensively of sulphuretted hydrogen still retains free oxygen, in traces readily indicated by this test.

Water may be *boiled* indefinitely, even boiled away altogether, but retain to the last traces of free oxygen.

Common salt expels all the oxygen from water (with certain precautions); the true explanation of its preservative power, etc., etc.

The Analyses.—All these figures are calculated on the basis of one United States gallon equalling 231 cubic inches of distilled water, each cubic inch weighing at 60° Fahr. 252·5 grains, making that gallon 58,327·5 grains. Some estimate it at a slightly different figure, but the difference is so trifling as to be immaterial.

Immediate Results of Analyses of Samples of the Passaic Water, expressed in grains and fractions thereof, per U. S. gallon of 58,327·5 grains.

Constituents of the Residues from Evaporation.	Settled Waters, taken October 10, 1872, at Belleville.			Analysis of 5 gals. of Unsettled Water, taken day by day from Hydrant in Hoboken. Winter average, December and January.
	Extreme Low Tide.	Extreme High Tide.	Receiving Reservoir.	
Sulphuric Acid	·6462	·7760	·6500	·2012
Nitric Acid....................	·1925	·3383	·2409	·2800
Carbonic Acid......	·4100	·2000	·2500	·2880
Chlorine......	·1505	·2923	·2163	·1520
Phosphoric Acid	·3800	·1780	·2001	·1202
Silica	·7910	·1120	·4000	·6344
Lime..........................	1·0400	1·1974	1·1120	·8037
Magnesia......	·3580	·4930	·4100	·3950
Potash	·0987	·2500	·2375	·1375
Soda...............	·1857	·4200	·3840	·2730
Ammonia......................	·0100	·0038	·0088	·0050
Peroxide of Iron...........	·1170	·0562	·0830	·0699
Alumina........................	·1660	·0956	·1322	·0868
Humic, or Peaty Acids (by difference).......	·6007	·2638	·3612	·6136
Proteine Derivatives, or "Albumenoids"	·0437	·1066	·0810	·0467
	5·1900	4·7830	4·7670	4·1070

It will be observed that the amounts of volatile and combustible matter are not given, as is usual (these being duly classed as "organic matter"). In the case of this water, these are in large measure made up of nitric acid, carbonic acid expelled by the silica, and oxygen from the conversion of the sulphates into sulphides.

The Sediments.—Before the settled water was pipetted off from the sediment, in each case, a mark was made on the bottle at the surface of the liquid. The sediments were carefully detached from the glass in every part by bent rubber-tipped glass rods, washed with some of the same water into small beakers, from which, after settling again clear, they were transferred to weighed watch-crystals, dried at about 100° Fahrenheit, and weighed. The volume and weight of the water were then found by filling up to the mark from a calibrated measuring-cylinder.

Estimates of the Dissolved Saline Contents of Passaic Waters; founded on Analyses; expressed in grains and fractions thereof, per U. S. gallon of 58,327·5 grains.

Theoretical Constituents of the Residue from Evaporation.	Samples taken at Belleville, Oct. 10th, 1872. Thoroughly settled before Analysis.			Sample of 5 gal. from Hoboken Hydrant, taken gradually during 20 days in Dec., 1872, and Jan., 1873. Evap'd in platinum.
	Extreme Low Tide.	Extreme High Tide.	Receiving Reservoir.	
Sulphate of Lime..........	1·0985	1·3192	1·1050	·3420
Nitrate of Lime............	·2923	·5137	3288	.4252
Phosphate of Lime—tribasic.	·8300	·3847	·4368	·2624
Carbonate of Lime........	·0677	·4545	·5681	·6545
Carbonate of Magnesia ..	·7258	——	——	——
Chloride of Sodium... ..	·2480	·4817	3564	2505
Soda......	·1190	·1652	·1993	·1402
Potash........................	·1190	·2500	·2375	·1375
Magnesia.....................	·0124	·4930	4100	·3959
Lime...........................	——	·0158	·0143	·0090
Silica	·7199	·1120	·4000	·6344
Hydrated Peroxide of Iron....................	·1375	0 657	·0970	·0817
Hydrate of Alumina......	·2530	·1457	·2015	·1323
Humic or Peaty Acids (by difference)..	·6007	·2638	·3612	·6136
Ammonia, free and combined (or as Urea)......	·0100	·0038	·0088	·0050
Proteine Derivatives, or "Albumenoid" matters	·0437	·1066	·0810	·0467
Total Grains per U. S. gallon......	5·2766	4 7906	4 8067	4·1300

These bases probably exist in the water in connection with the peaty acids, though perhaps in part with carb. acid, which is expelled and replaced during the evaporation, by the peaty acids and the silica.

Sedimentary Deposits.

WATERS.	Extreme Low Tide Oct. 10, 1872.	Extreme High Tide Oct. 10, 1872.	Receiving Reservoir Oct. 10, 1872.	Hoboken Hydrant Nov. 1, 1872.
Amounts operated on, in grains,	61·729	62·470	60·186	58·327
Grains found, per U. S. gallon,	1·008	0·504	0·479	0·493
Prof. Horsford, October, 1851,		1·262		
Prof. Chandler, Hoboken Hydrant water of May 3, 1872				0·520
Total solid contents of unsettled waters; that is, the sum of these sediments and residues of evaporation,	6·198	5·287	5·246	

In the low tide water and receiving reservoir, appeared quantities of a green confervoid growth, characteristic of standing waters, much more perceptible on the watch crystal during dessication than at any time before. There was more of it in the low tide water. In the high tide sediment there was not the slightest trace of this perceptible to the eye.

Microscopic Examinations.—The general results of these were confirmatory of the above. The low-tide sediment was apparently made up chiefly of beautiful spicular and fibrous organisms, with bunches of their spores, doubtless belonging to the *confervæ* (fresh water *algæ*, frog-spittle). These were mingled with *very minute* translucent grains, looking like rounded sand, but more probably clay. In the reservoir sediment, there was more of the sandy looking matter and less of the organisms. Curious to say, however, though the search was made patiently for a long time, no trace of fibre or spore or anything organized whatever, appeared in the high-tide sediment. It was all a fine sandy looking mud. As all these waters had been kept under precisely identical conditions, and as the germs of this vegetation must have been equally dispersed through all of them, this is regarded as a most surprising fact. That the Newark sewage, or some other influence removes, between low and high tide, from the water, something essential to the germination and growth of vegetation, or else imparts something inimical thereto, are the only inferences to be drawn. Some of the green mass of confervoid fibre, removed from the edge of the watch crystal, of the low-tide sediment, and burned to ash on platinum foil, left a voluminous mass of white spiculæ, which, transferred to a platinum loop, fused readily to a transparent glass, and behaved generally like a mass of phosphates, but the quantity was too small for analysis. An attempt was made to determine, by incinerating, the amount of vegetable matter in the two sediments containing it, assuming that the mineral portion of each retained, when dried in air, about the same amount of water. The following are the results:

	Water per 100 of Sediment. (Estimated for 3 and 4).	Anhydrous Mineral matter, per U. S. gallon of water.	Vegetable Growth, in one U. S. gallon, in dry form.
1. High Tide,	20·00	0·403 grain,	*None.*
2. Hydrant,	23·38	0 368 "	(not determined).
3. Low Tide,	8·32	0·349 "	0·561 grain.
4. Reservoir,	15·01	0·255 "	0·152 "

The results in the last column of this little table must be regarded as among the most interesting obtained in the course of this investigation. The ash in each case contained iron, and had apparently about the same tinge of red.

Chemical and Sanitary Discussion of the Analyses.—These analyses furnish many points of interest in a purely chemical view, but it would be inappropriate to give much space to any of these, which have no *direct* sanitary bearing. Among the most important are the changes incurred by the water while being swept backward and forward past Newark by the tides. These are (see Table II):

A small increase of sulphuric acid, lime and magnesia.

A large increase of the nitric acid, chlorine, soda and proteine derivatives.

A diminution of the carbonic acid, phosphoric acid, iron, alumina, and humus compounds.

A large diminution of the silica.

The increase of nitric acid accounts for a large part (say half) the loss of carbonic acid. The phosphoric acid may very well be believed to have gone down with the alumina and iron, taking with it humus and some ammonia, and if, as seems probable, the silica is really held in solution by the humus acids, this would precipitate also. The loss of these ingredients *possibly* accounts for the fact that no confervoid growth whatever appeared in the bottle of high-tide water, as stated under the head of sediments.

Among these chemical points, of sanitary bearing, doubtless the most striking and important of all is the *increase* in the quantity of nitric acid in the water brought up by the rising tide past Newark, which increase is ·1458 grain per gallon. If this is regarded as having proceeded from albuminous or proteine bodies, it represents ·923 grain of these, which, added to the increase in the quantity of such bodies found directly, makes ·986, for simplicity say one grain per gallon, of dry products of putrefaction of albuminous matters, or say equivalent to 4 grains of decomposing egg-albumen per gallon.

If we suppose one *rotten egg*, weighing about 800 grains, to be beaten up with 200 gallons of low-tide water at Belleville, it might represent the *initial* effect of the Newark sewage, according to this rather unsavory calculation. What a rapid change is here shown to have occurred during the short run that the water has had, only between three and four miles, from New York up to Belleville.* The sewage matters have been constantly suffering a process of decay, slow combustion, or *eremacausis* (as it was called by Liebig), through the agency of the free oxygen held in solution in the highly aerated water pouring in every day from up stream; and, as the analyses further show, the residuum of the albumen or proteine derivatives, left from the Newark sewage, over and above those brought down from up stream, is but ·063 grain per gallon, and the whole amount in the high-tide but about one-tenth of a grain, equivalent, *if putrid*, to one rotten egg in 2,000 gallons of water. But it is unreasonable to suppose that this substance, whatever it may be, which yields ammonia with the powerful reagent of Wanklyn & Chapman, is still in a state of *putrefactive* change, or even *capable of such change.* Proteine bodies yield many products of metamorphosis which are highly stable. Dr. R. Angus Smith, in his writings on these subjects, refers repeatedly to waters answering to the Wanklyn-Chapman test, which are nevertheless incapable of putrefaction, and in one place infers the existence of some proteine body not susceptible of this change.†

The agency which effects this change, between Newark and Belleville, is that universal one which has long been studied by chemists, known as *nitrification.* Animal matters containing *nitrogen*, with *water*, *oxygen*, *alkaline* substances, and always *time*, are the conditions requisite to its progress. These analyses show the Passaic water to be an alkaline water, and we have present all the conditions for nitrification. The surprising circumstance is the short time apparently required.

The ·3383 grain of nitric acid in the high-tide water represents, when calculated as saltpetre, ·6327 grain thereof, and this, when calculated on the average daily flow of the Passaic water, is 90,400 lbs. of saltpetre per day (about 16,500 tons per year). About 40,000 lbs. per day of this is furnished by Newark, the other 50,000 by the rest of the inhabitants, both man and beast, oppidan and rural, of the 900 square miles of Passaic water-shed above. When we remember that this nitric acid represents but a fraction of the nitrogen of the effete matter from which it came, and that this nitrogen was itself but a small percentage of the whole, it is clear that these thousands of pounds of saltpetre must represent hundreds of thousands of pounds of effete matter cast daily into the waters of the Passaic. Some eminent chemists, particularly in England, have thrown doubts upon the conclusions drawn by others from nitrates, as indicating previous sewage contamination; claiming that nitrates may be washed out of older geological formations, and so on. In our present investigation we may cast aside this objection, as the Passaic basin contains nothing of the sort that could yield nitrates. All these must have come from the excreta of men and animals, the washings of barnyards, manured soils, etc.

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* On further consideration, since writing the above, it appears probable, however, that much of the water brought up by the high tides has run past Newark, back and forth, several times, and has had therefore a far longer course of flow than this. Still the *average* result should be the same. H. W.

† *Chemical News*, June 11, 1869, page 281.

We have now considered the bright side of the picture: let us look on the reverse. These samples of water were collected in cool autumn weather. Would analyses of the water in the heat of the summer show the same or like results, when the water is warm? The *warmer* the water, *the less oxygen it can absorb* under given circumstances. It is the oxygen dissolved *in the water* that does the work, and not that of the circumambient air, which can act but superficially.

In 1857, the great chemist, Bunsen,* published determinations of the capability of water to absorb oxygen at different temperatures. The following figures are extracted from his tables. One hundred volumes of water, *when saturated* with oxygen, contain at the temperatures specified respectively (reduced to Fahrenheit degrees, the intervals being 5° C. or 9° F. apart):

At	32° (freezing)	41°	50°	59°	68°	
	4·12	3·63	3·25	2·99	2·84	volumes.

As the temperature of the water during the summer heats ranges ten or fifteen degrees higher than the last figure (which is as high as Bunsen gave), we may assume as approximate that the power of the same water to absorb oxygen, *ceteris paribus*, is twice as great in the winter cold as in the summer heat. The qualification is used, because barometric pressure, and composition of the water itself, particularly the latter circumstance, have large, and even overwhelming influence, as has been ascertained by experiments with the new methods before referred to.

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* Gasometry, Roscoe's edition, pp. 153 and 286.

In addition to this momentous fact, that water can absorb at the utmost but half as much oxygen per gallon in summer as in winter, another fact, also important it may be, must be remembered. The volume of aerated water that flows down from above tide-water in the former season, is *far less* than at other seasons. There are no means of exactly determining the difference at present at hand, except by comparison with other rivers in nearly the same latitude. The difference, for instance, between the maximum flow of the Hudson at Albany in March, and its minimum in July, is as *seven to one!* If this rule holds as to the Passaic, the amount of oxygen brought down by the stream, to attack and destroy the fæcal and urinary compounds cast into the river at Newark, is in July but one-fourteenth as great as during the flooded seasons. This, however, is doubtless too strong a view, as the alternate sweep of the stream up and down at each tidal change, even to some extent as far up as the Dundee dam, some seven miles above Belleville,* must assist largely in the aerating operation, and this operation is therefore by no means wholly dependent on the down-flow of the river itself. Still, when we consider that in midsummer the heat intensifies putrefaction, and that the amount of available oxygen to destroy its products is largely diminished by the enfeebled solubility of oxygen in the water, it would appear that we have a reasonable solution of the unpleasant odor and taste that the water has of late years sometimes acquired in July.†

Moreover, looking to the future, though there seems every reason, on considering these analyses, to believe that no detriment to the public health has *up to this time* arisen from the use of these waters, there seems to be no good reason to deduce the slightest confidence or belief in an indefinite, or even a long continuation of this immunity. Newark grows rapidly, and grows towards Belleville; and the distance from your pumps within which it is safe to have a common sewer emptying into your river has not yet been determined.

Remarks upon Aeration of Potable Waters.—It will probably not be expected that space should be occupied with authorities, quoted in support of the proposition, that a necessary condition of a healthy water is good aeration. The universal experience of mankind has taught them this. A well or an underground cistern may be deprived of light (indeed the less light the better), but *air* it must have, or it putrefies in spite of all.

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* I was informed at Belleville that the tides there average 5 and 12 feet, and are three-quarters of an hour later than at New York. H. W.

† I was told by a leading butcher of Hoboken, a reliable man, that he did not dare to use the hydrant water in the summer season to wash his meat, as it quickly turned the latter green; a fact which did not hold when well water was used. H. W.

Dr. Letheby has recently produced facts to show that the death-rates of British towns are proportional to the absence of the earthy bases from the water supply; and has argued that these bases are needed for the making of blood, bones, etc. His facts are undeniable, but the present writer has a very different explanation to suggest, namely, that these bases are needed by oxygen in its work of nitrification and destruction of putrefactive matter, an explanation which seems far more satisfactory.

Early in this investigation, when your reporter first began to see the nature of the process going on in the Passaic waters, the immediate necessity forced itself upon him of possessing reliable methods of determining the amount and rate of aeration of water. On trying the methods heretofore in use, they were found far from reliable or delicate enough for the purposes required. He therefore cast about him for new means, and in the course of time and experiment settled upon a reagent introduced long since by Liebig, for determining oxygen in the air, and widely used in gas analysis, called *pyrogallic acid.* (As it is not an acid, it is preferable to follow some of the English chemists, and call it *pyrogalline.*) The details of the methods that have been founded on the use of this agent in water analysis must be reserved for communication to the chemical world in another form. Great difficulties were met with in the practical application, but have been satisfactorily overcome. It furnishes now the means not only of determining the amount of oxygen already existing in the water, but also of determining the rate of its absorption by different waters, and under different circumstances.

Considerations in reference to new sources of water supply, or new modes of supply, are not within the province of this Report; but it may be considered as pertinent for your reporter to submit to your Board any views looking towards improvements of, and making the best of, the present supply and mode of supply: premising, however, with emphasis, that these are only intended to be regarded as *suggestions*, which, by awakening attention to the subject, may possibly give rise to far better and more practicable plans.

Now, that we are acquainted with the nature of the wonderful process of regeneration and revivification that goes on in our water, it behooves us, in fact, if within our power, to promote it; to assist nature, and to study the means of doing so, without delay. What conditions, then, should we supply to the water, in order to promote this process? Evidently two, oxygen and time; or, as it may be better to express it, opportunity to absorb oxygen, and time for the oxygen to do its work.

One suggestion to be thrown out here amounts simply to this: that, if means were adopted to keep the water in one of your reservoirs in a condition of gentle agitation, or rather intestinal motion, in every part, so as continually to turn up new surfaces to the air, the absorption of oxygen would be enormously promoted. To support this assertion, it may be stated that by the new method, the water taken from the receiving reservoir on the tenth of October last, was found, when standing *at rest*, at 60°, to absorb oxygen from the air in 12 hours to the depth of 4·75 inches, and in 24 hours to the depth of but 7·5 inches. After this, the absorption became very slow, and in two days almost imperceptible. The motive power for keeping the reservoir water in motion would be trifling, and readily obtainable from the inflowing water.

The immediate objection made will be that one function of the reservoirs is to cause the water to *settle* and deposit its sediment; and that motion will interfere with this. This is by no means certain, as it is very probable, from the analytical results presented in this report, that little or no settling is actually accomplished, in your distributing reservoir at least. The water from the receiving reservoir of October 10th, gave 0·479 of sediment, while that from the hydrant in Hoboken of November 1, gave 0·493. The latter result agrees also with that of Professor Chandler, who found, in hydrant water of May 3d, 0·520 of sediment. One reservoir might, at present, be sufficient for settling purposes.

The applicability of this idea would of course be greatest during those seasons when the reservoirs, lying in hot still sunshine for whole days together, are obviously in the condition, more than any other, of stagnating pools, in whose bosom all kinds of organic changes, including putrefaction (in the absence of abundant oxygen), as well as germination, may well be believed to find most favorable conditions.

Still another suggestion, also of a very simple character, which ought to have considerable efficiency for a time, is to remove, not your pumping works, but the point from which you take the water from the river, some miles further away from Newark, leading it of course to the works by a canal.

*The Passaic Water-Shed.**—Not being able to find any data for the computation of the flow of the Passaic River, it was determined to make a careful measurement of its water-shed or basin, which was accomplished by the method of weighing.

Three sections of the large geological map of the State were found, on being pieced together carefully, to cover all but a very trifling corner of the water-shed, at the head-waters of the Saddle River. The wonderfully tortuous rim of the basin was now very carefully traced out all round, following a medial line between the heads of the small tributaries and those of the adjoining basins, using a soft pencil. Tracing muslin of the best quality was now superposed, and the former line followed round again. Small sharp scissors were now called into requisition, the water-shed cut out, carefully rolled up, and weighed on a delicate chemical balance. 120 square inches of the same muslin were then carefully measured out, cut out in the same way and also weighed. As the scale of the map is two miles to the inch, this represents 480 square miles. The weight of this and of the whole water-shed being known, it becomes a simple rule-of-three sum.

Two such maps were made. One, on which I endeavored roughly to trace out the river and its main tributaries, I present herewith, that you may be enabled to inspect the form of this singular basin. On the other were traced out, before detaching it, the boundaries of the different geological formations that are included within the basin, also the State line between New Jersey and New York. This latter map was dissected, and weighed piecemeal, to determine these different areas.

The following are the figures obtained:

Area of Passaic Water-Shed, . . .	908	sq. miles.
Area of the New York portion thereof, . .	148·5	"
Area of the Crystalline Rocks of the Highlands, within the Water-Shed, ...	484·5	"
Area of the Brown "Sandstone," and Trap (Triassic) formations, ...	423·5	"

[It was the original intention to enter into some geological, or rather lithological discussion, based on these measurements, and the bearing of the results of the analyses upon the composition of the rocks, the more especially as your reporter has spent much of his life in the study of the rocks, minerals and general geology of northern New Jersey. It was intended to calculate the rainfall in the basin for each month in the year, and other interesting matters besides; but it is now feared that the necessary limits of this report would be surpassed.]

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* A chapter containing a discussion of former examinations of Passaic water is omitted in this abstract.—Ed.

The water-shed of the Passaic, it thus appears, is much larger than had been anticipated, and it is evident that the estimates heretofore accepted, of the average flow of this stream, are greatly below the truth. The annual rainfall is known to be more than 50 inches,* and a simple calculation shows, therefore, that the total amount of water received by the Passaic and its tributaries in one year, is 782,100,000,000 gallons, or 2,115,000,000 gallons per day, on an average. As it is usual to allow a loss of one-half, however, by evaporation, it will be safe to call the average daily flow of the Passasc one thousand million gallons. This is' not much less than the average assigned to the river Thames, 1,350,000,000 gallons; although that river is more than 250 miles long and ours but 80 miles. This fact serves to illustrate the very remarkable character of the Passaic basin. The rainfall, however, in the Thames valley is but 27 inches. The Croton water-shed measures 339 square miles, so that our water-shed is 2·7 times the size of that which supplies New York City. Nine-tenths of this water-shed lies above Paterson, and its drainage flows over the falls at that place. We have water enough (with reservoirs of sufficient capacity and in proper locations) for all our cities for centuries to come, not only for domestic, steam and manufacturing uses, but even for water-power, where small powers are required (as for sewing-machines, for example). The problem is, how to make it come to our cities without constantly augmenting cost. This, however, is a matter outside the scope of the present report.

The Sewage of Paterson.—Included in the instructions upon which this investigation was based, were examinations into the question that has caused alarm to some, whether the Passaic water is not possibly contaminated, and rendered poisonous, discharged from the dye-works, and other works in which chemicals are employed, in Paterson.

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[*] The mean annual rainfalls were, for a series of years:

For Newark, ...	50·2
For Paterson, ...	51·2
For Dover, ...	50·1
Mean, ...	50·5

It is among chemists an accepted fact, that no such substances are thrown by manufacturing cities into rivers, in any *permanent* form of solution ; but, as many who use our water would be much better satisfied with direct chemical evidence on this head. as much time was spent in these examinations as could be reasonably taken from things of greater profit, visits were made to a number of these works, and it was ascertained that there was a possibility of small quantities of waste lead and copper solutions finding their way into the drains. The aniline colors, some of which, it has been suggested, might carry *arsenic* into the river, were stated to be too costly to allow of any waste. They are always used up entirely. It has been stated on a previous page that samples were taken from two of the main sewers, and from the river below all the sewers at the Straight Street Bridge. All these, though kept in a room without fire, tightly stoppered, and in very cold weather, began straightway to putrefy, and to evolve free sulphuretted hydrogen. As neither lead, copper nor arsenic can remain in solution for a moment in water containing sulphuretted hydrogen, this was pretty conclusive ; yet it was deemed best to make a crucial experiment. To a portion of each water was *added* small quantities of solutions of lead, copper and arsenic. After settling for twenty-four hours, the filtered liquids were rigidly tested, and no trace of either of these three metals could be found left in solution.

It should be added, for the behoof of chemists, that all these samples were absolutely neutral to test papers ; a somewhat surprising fact, when it is stated that the samples were collected on a *washing day* (Tuesday, from 2·30 to 3·30 P. M.), and it was expected that they would be perceptibly affected by the alkali of the soap. The amount of sediments deposited by these samples respectively, after standing at rest one month, were as follows :

WATER.	Quantity employed.	Grains of dry Sediment per U.S. gallon.
River, from Straight St. bridge,	530 grammes.	1·101
Prospect Street sewer, . .	578 "	2·119
Paterson Street sewer, . .	680 "	10·194

It had been intended to report other analytical results obtained in connection with the sewers, but as the above comprise all that have any *obvious* sanitary bearing, it is judged better not to swell the report with them.

Some microscopic observations were made on the above sediments, but nothing observed of much interest, except the somewhat curious fact that the river water taken from the Straight Street Bridge gave a sediment singularly crowded with fragments of *fibres* of various kinds, derived apparently from different textile tissues.

Summary.—1. The basin drained by the Passaic River contains over 900 square miles of territory, and receives annually over 782,000,000,000, or, as daily average, over 2,100,000,000 of gallons of water.

2. Allowing an average loss of one-half by evaporation (doubtless an over-estimate), the annual flow of the river at Newark is 390,000,000,000 gallons.

3. The actual daily flow varies within wide limits, as yet undetermined, possibly between 200,000,000 to 300,000,000 per day during the dryest summers, and 2,000,000,000 or 3,000,000,000 or more during times of flood.

4. The daily flow, with the river at an average height, may be called 1,000,000,000 gallons; more than nine-tenths of which, say 900,000,000, must flow over the Falls of Paterson. The whole discharge of this river is 2·7 times that of the Croton River, which supplies New York.

5. The water belongs naturally to the class known as "peaty" waters, though not largely imbued with this contamination, at least, in the lower part of its course.

6. From the Falls down to the mouth, the peaty matter gradually diminishes in amount.

7. The water is alkaline in character, or at least has a considerable excess of basic over acid constituents. The amounts of lime and magnesia vary at times, but do not differ much from the average of the Croton water.

8. In the lower part of its course, at least, the river contains in solution quantities of *nitrates*, sufficient to be easily and accurately determined by delicate chemical analysis.

9. These nitrates are increased in quantity by flowing through the city of Paterson, and again nearly doubled by flowing through Newark.

10. These (or their nitric acid) are derived from the oxidation of the animal excretions and other similar refuse that pass into the river at Newark, Paterson and elsewhere, from sewers, slaughter-houses and other sources; materials that would otherwise remain in the water in a state of putrefaction.

11. There is no reason to believe that these nitrates affect health in any way whatever.

12. The oxidizing power of this alkaline river water, in the *autumn* season, is so great, that but slight traces of the sewer-matter can be detected, after flowing but four miles through the channel; so little being left that the water acquires no odor on being kept in a closed bottle at 60° F. for one month.

13. There are as yet no results on record in the way of tests during the *summer* season, when the water absorbs much less oxygen.

14. This water allows the germination, and supports the growth, of green confervoid vegetation in its bosom, under favorable circumstances, until after it has passed through the city of Newark, when it *loses this power;* losing some of its constituents at the same time, while gaining others, and changing materially in composition.

15. In the opinion of the undersigned, it will not be safe to have sewers from the city of Newark, *at any season*, discharge into the river nearer to the pumping works than they do at present; unless the water is conducted to the pumps from a point correspondingly further up the river.

16. This latter precaution is suggested for adoption at once, so long as the present pumping stations are adhered to.

17. It is suggested also that the practicability be examined into, by the Engineer of your Board, of keeping the water, in at least one of the reservoirs, during the summer months at least, in a condition of slow intestinal motion or agitation, in order to promote absorption of oxygen, and consequent destruction of organic impurities.

18. No metallic or mineral poison can be detected, as cast into the stream at Paterson; nor could any such remain in solution therein for any length of time.

All of which is respectfully submitted.

The St. Gothard Tunnel.—The total extent of advance in this undertaking, at the end of March last, was 806·4 feet. About 800 workmen are employed. Considerable trouble is at present being suffered on account of the flow of water into the workings through the micaceous rock, which at one time amounted to seventy-five quarts per second, and greatly delayed the progress of the work.

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EDITORIAL.

ITEMS AND NOVELTIES.

An Expansion Boring Tool.—The accompanying plate represents a useful tool of this description, patented and manufactured by C. Van Haagen & Co., of Philadelphia. The plate shows the tool in perspective and sectional views.

It is adapted to all tools having either revolving or stationary spindles, such as the lathe, the various vertical drill presses, horizontal boring mills, pulley turning and boring machines, &c., &c., by attaching it to any one of the spindles of the above-named machines.

The object to be bored or turned is secured to the face-plate of a turning-lathe, or to the bed-plate of a boring machine, by any suitable appliances, and the tool is secured to a spindle, which can be fed forwards, such, for instance, as the spindle of the pocket-head of a lathe.

The tool consists of a slotted hub, F, into which is screwed a tapering shank for attachment to the spindle. Into the slot of the hub F is fitted the inner end of an arm, G, and through the latter, as well as through the hub, passes a tapering pin.

A screw or worm, D, fits snugly, but so as to turn freely in the slot of the hub F, and the thread of this worm is adapted to the teeth of a segment, P, of a worm wheel formed on the arm G, and arranged concentrically with the tapering pin on which the worm rotates, so that on turning the worm, which in the present instance can be done by a square tool adapted to a square hole in the worm, the arm may be turned to any desired angle.

Towards its outer end the forked hub F is made slightly tapering, to receive the tapering sleeve, E, against which bears another sleeve, C, adapted to the cylindrical portion of the hub, and against the latter bears a nut, B, on the threaded end of the hub. On tightening the nut, the tapering sleeve E will be forced outwards through the medium of the sleeve C, and the two halves of the hub, which are slightly elastic, will be forced towards each other, thereby firmly gripping the arm G.

The following sizes of these tools are made by the firm:

No. 1 bores from 1$\frac{7}{8}$ inches to 16 inches.
" 2 " " 1$\frac{3}{4}$ " " 13 "
" 3 " " 1$\frac{1}{2}$ " " 11 "
" 4 " " 1$\frac{3}{16}$ " " 8 "
" 5 " " 1 " " 6 "

This will be found a very useful adjunct tool to any machine shop, because of its universality, dispensing, as it does, with the necessity for using boring bars and cutters in a majority of cases, and the very satisfactory character of its work.

Combined Iron and Steel.—A method of combining iron and steel, which, from its simplicity, is worthy of observation, has been invented by Mr. Elbridge Wheeler. We have before referred to this process, though briefly, and take this opportunity of giving a more extended notice, with illustrations of the same.

The invention embraces not only the complete union of distinct metal surfaces, but includes the subsequent working up of the combination into various forms—tubular amongst the rest.

The desirability of effecting a combination of these metals, that shall preserve the toughness of the iron with the hardness of steel, has long been recognized, as the high prices paid for the hand-made material in several trades amply indicates. The processes heretofore successfully operated, have, however, been too tedious, costly and generally upon too small a scale to render them applicable to the uses of the rolling mill. This desideratum the inventor claims to have accomplished, the process consisting in general terms of the uniting of iron and steel by bringing them to a welding heat in one pile and simultaneously, and then manipulating them by rotary motion.

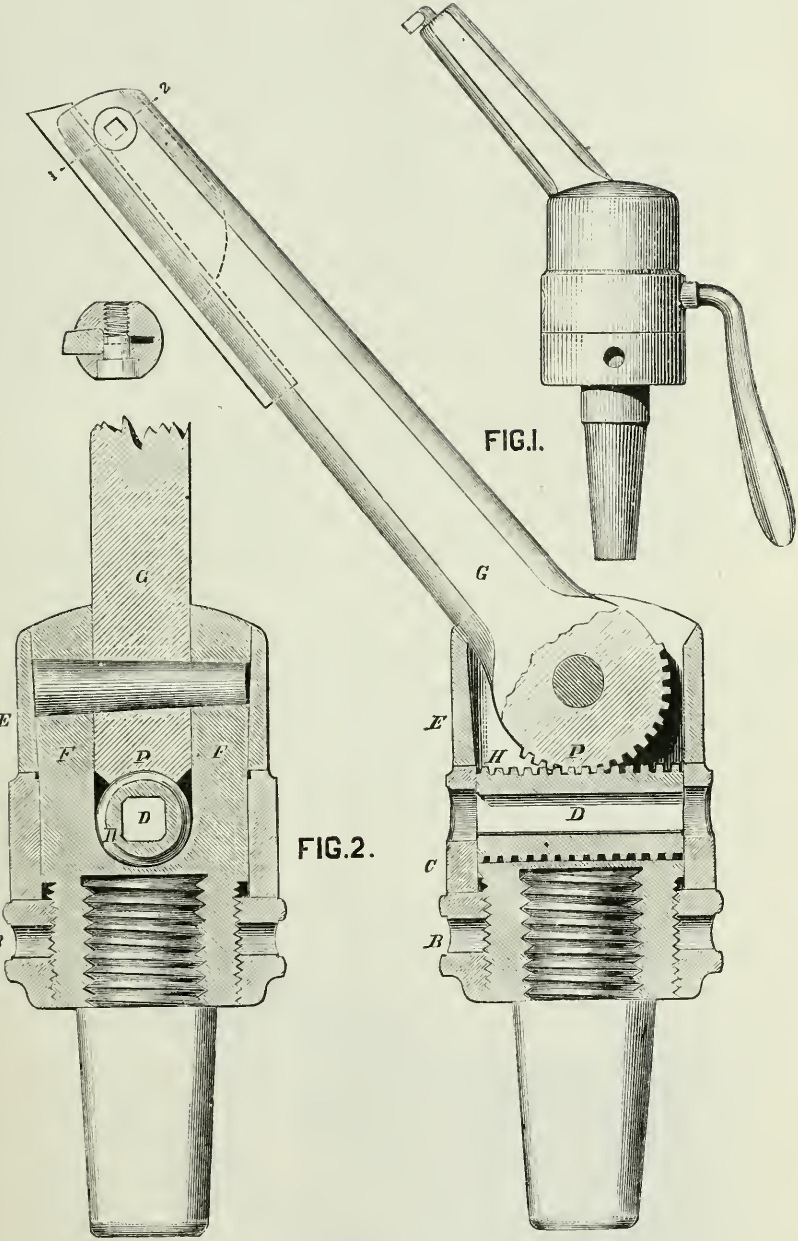


FIG. 1.

FIG. 2.

EXPANSION BORING TOOL.

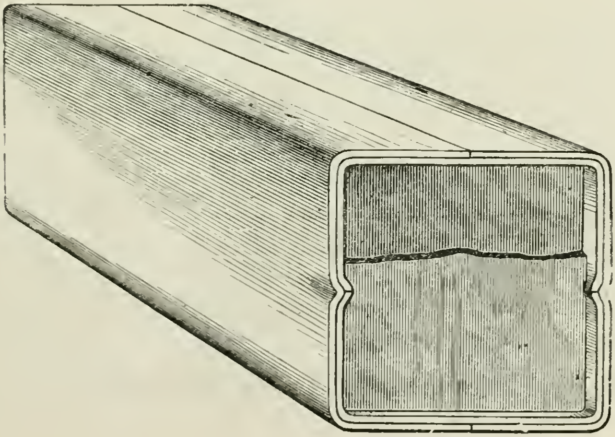
MANUFACTURED BY C. VAN HAAGEN & CO.
PHILADELPHIA.

The difficulty heretofore met with in attempting this method of union, has been that steel exposed to the high temperature requisite to bring iron to a welding heat, is "burnt," while, at the same time, the use of fluxes but partially obviate this difficulty.

The objects sought, namely, the perfect union of the two metal surfaces, without injury to the character or quality of either, as well as the manipulation of the resulting combination into forms straight or tubular, Mr. Wheeler accomplishes by placing the steel in an iron case, made as nearly air-tight as possible, whereby it is protected from the influences of excessive heat. In this way are produced merchant bar, rounds, squares and flats, all sizes; plate for various uses; bar for specialties, such as car axles, wagon axles, shafting, slide-bars, piston-rods, etc.; railroad rails for steam and horse railroads; and tubular forms, suitable for such uses as car axles, marine shafts and bridge columns. These various forms can be produced, with varying proportions and relative position, of the iron and steel entering into their constitution in the bar and plate as well as in the tubular forms, while in the latter it is possible, by a simple device, to produce varying diameters in the same tube.

Three varieties of metal are recognized by the inventor—1st, an iron coated steel slab or bar or plate, in which steel predominates; 2d, a steel centred iron, where iron predominates, and, 3d, combination proper, where the steel is so proportioned and placed as to endure the most wear and sustain the greatest strain. In the illustrations herewith given, the black portions represent the iron, and the shaded parts, steel.

Fig. 1 represents an ingot of steel inclosed in an iron case. This



case is made preferably in four sections, so as to break joints at the sides, which project over the ends sufficiently to receive an end plate of iron held in place by a slight inbending of the sides. Instead of an ingot, steel slabs, cast or even Bessemer steel scraps may thus be encased. After the heating, and reduction in the rolls, to a square or flat, the resulting mass would show a bar of steel coated with iron welded to, and forming a part of it, (see fig. 2.) The coating of iron can be varied in the thickness at pleasure, according to the uses to which the product is to be put, and it is especially well adapted to subsequent forging. Fig. 3 shows a steel-centred iron bar, suitable especially for set-screws, punches, etc. Any desired proportion of steel may be used and any exterior form given to the bar.

Fig. 2.

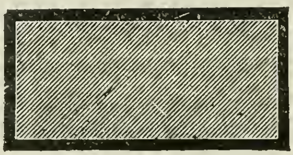
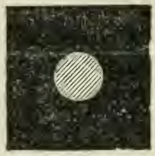


Fig. 3.



In the production of rails, the simple process of combination described above comes very admirably into play. It is, however, to the production of tubular car axles that a great field of usefulness is to be anticipated for the process. These hollow axles are produced without the aid of a mandril, by simply piling up about each other sectional tubes of iron or steel, in the proportions and positions required in the product—the piling being done in such a way as to break joints. So arranged the pile is heated and rolled, when a complete union is effected. It is clear that by simply putting in the interior of the pile smaller sections of iron, it is possible to vary the diameter of the axle at will. So that the shell of iron may be turned off from the journal ends of the axle, leaving the steel for bearing without lessening the strength.

For this tubular axle there are claimed a number of advantages—of which the more prominent are, that the tubular form affords, with less weight, more strength than the solid axle—the saving in weight amounting to nearly 25 per cent., implying a considerable saving in expense of running trains, and the increased life of the axle from the character of the combination.

A Tunnel through the Rocky Mountains.—A project no less gigantic than the piercing of the Rocky Mountains, is announced as about to be commenced. The projected tunnel will, if completed, be carried through the Rocky Mountains from a point near Black Hawk, and will come out in the Middle Park. It is said that the project is fully inaugurated, and that its projector is on the ground with ample means and labor at disposal to prosecute the work to completion. The tunnel will be about twelve miles long. Its greatest depth will be 6000 feet, at James Park. It will make the Middle Park readily accessible from the eastern part of the territory, will indicate the mineral and geological character of the region, and will not fail to attract attention to the region, as the scene of an engineering enterprise nearly twice as difficult of accomplishment as the famous Mont Cenis tunnel.

It is stated that early next year work will be commenced from Middle Park. Already considerable work has been done.

The mountain has been graded down for the face of. the tunnel; a flume, 1300 feet long, has been built from the creek, by which a fall of 25 feet is obtained for the purpose of running an overshot wheel, by means of which the tunnel is to be supplied with air; a strong levee has been built, to prevent the waters of the creek from overflowing and embarrassing the operations in the tunnel.

The main advantages to be derived from its construction are stated to be that it will open up new veins, and afford a thorough knowledge of the course of mineral veins; that it will afford a means of working the discovered mines cheaply and rapidly, and that it will develop the resources of the region by the increased facilities for transportation which its construction will afford.

The Baltimore Underground Railways.—The city of Baltimore is now in possession of a splendid underground railway system, in which respect it stands alone amongst American cities as the inaugurator of this great improvement, and which her sister cities must infallibly imitate sooner or later. There are now two distinct lines of tunnels in Baltimore, which, according to a contemporary, have been completed at a cost of nearly five millions of dollars, whereby nearly all the various railways centering in the city have been brought into connection, greatly adding to public convenience and facilitating business intercourse.

The Underground Railway consists of the Baltimore and Potomac Tunnel, of which the western portal fronts on Gilmore street, whence it extends in a northeasterly direction through the city, under some twenty-nine streets and avenues, emerging at North avenue, where it joins the track of the Northern Central Railway.

The Union Tunnel extends from tide-water at the Canton portion of Baltimore, northerly and then easterly, under some thirteen streets and avenues, to the Northern Central Railway.

The total length of the Baltimore underground railways is 3½ miles, of which about two miles are closed tunnels, and the remainder open cuts, over which the streets are carried on bridges. The tunnel arches are from 22 to 23½ feet high, and from 26 to 27 feet wide, five rings of brick thick, backed with rubble masonry. Only a portion, where the ground was soft and springy, required the invert arch. The springs of the arches are of masonry.

Passengers can now pass through Baltimore by the new underground railway, thus shortening the time of transit from twenty to forty minutes. The tracks of the P. W. and B., the Northern Central, the Baltimore and Potomac, and the Western Maryland railways all connect with the underground railway.*

Coal-Cutting Machinery.—Comments have from time to time appeared in the technical press upon the applicability of machinery to be employed in the mining of coal. The statement is made that there are now several forms of coal-cutting machines in use in English collieries, working with great satisfaction. The machines in question work with compressed air. It is declared that the general adoption of this system of coal extraction would not only result in a very considerable diminution in the amount of waste, but would also very materially diminish the labor force now needed to keep up the extraction to market figures. So great is the estimated margin of saving on this latter score, that it is declared a force of 60,000 men only would be required to raise the 120,000,000 tons annually produced, instead of the 360,000 at present required.

The opinion, too, is very generally maintained that these advantages will be confined to localities where the veins of coal are comparatively thin. In England, for example, where the experiment has proven to be quite successful, the average thickness of the veins is from 2 ft. 4 in. to 2 ft. 10 in., while in the United States the bitumenous veins range from 4 to 8 ft., and the anthracite often from 25 to 40. To this very considerable difference in the thickness of the veins may probably be ascribed those difficulties in economic extraction which have thus far excluded the coal-cutting machine from the American mines.

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* Scientific American.

Improved Method of Construction *with Metals, Glass and other Building Materials.*—The process about to be described is the invention of Mr. William Haggett, and consists in giving to the materials used in construction a peculiar form, in virtue of which the strength and adaptability of the same to civil, military and marine constructions is claimed to be much improved.

The process, in general terms, consists in giving to plain plates or sheets, of uniform thickness, of the various kinds and qualities of metals, glass, tiles and other substances, compound undulated forms, the undulations crossing each other at right angles, or obliquely, or radially and circular. These forms, it is claimed, impart to the plates great lateral strength and rigidity, and as the undulations extend in opposite directions, they afford equal compensation for contraction and expansion in all directions; a desideratum of great practical importance in construction, since, if realized, it makes it practicable to attach the borders of such plates firmly to adjacent unyielding masses.

The process for undulating the plates is varied to suit the character of the material operated upon; some by direct casting in matrices of the desired form, others by being heated and then pressed between rollers, stamps, dies, &c., but in all cases it is necessary that the alternate convex and concave parts of the rollers, &c., accurately fit and work with each other. Most rolling-mills, it is said, have all the power necessary for carrying out this system of manufacturing metals, requiring only a supply of properly formed rollers.

The following estimate is claimed to represent the strength of the undulated over the plain plates: Iron and steel about two-fifths, galvanized iron, three-fifths; sheet tin, three-fifths; brass, three-fifths; zinc, two-fifths; copper, four-fifths; lead, three-fifths; cardboard, one-fifth; while glass is nearly doubled in strength.

In construction of the ordinary kind, the plates may be attached one to the other with some overlap—the corrugations permitting of a good fit—and then attached simply at the ends. An interior wall of similar character is also erected, and the space between the two filled with some non-conducting material, which shall make the building independent of the external temperature.

It is also designed to apply the same process to the speedy erection of forts, towers, batteries, and other works of defence, by constructing portable blocks, so formed as to interlock and become firmly bound together.

Bricks and tiles of this form are constructed and employed for roofs, sewer and wharf construction with great success. While applied to glass for skylights, illuminating panels in buildings or conservatories, there are claimed for it the several advantages of increased strength with no decrease of light, and nearly perfect absence of lateral expansion.

The above remarks indicate but a few of the numerous applications which it is proposed to make of this process, and have been selected with a view of giving some notion of the universality of its claims to usefulness.

Mechanical Stoking.—Mr. J. Somerville recently read before one of the English engineering societies a paper on charging and drawing gas retorts by machinery. The author first referred to the necessity of introducing machinery to perform labor of this kind both on account of the exhausting and demoralizing nature of the work of gas stoking, as also in consequence of the strikes amongst gas stokers, of which the recent strike in London was referred to as a notable example.

The author referred in his paper to the frequent attempts to accomplish this desideratum, mentioning the efforts of Clegg, Brunton, Michael, Green, Best and Holden in this direction. The plan described and recommended by the author of the paper consisted in an improvement upon the machine of Messrs. Best and Holden.

He employs two machines; one for drawing and another for charging, the retorts being served at both ends, and the machines following each other up in their work.

The author gave the results of working by these machines, which indicated that the cost of coking coal was 6*d.* per ton with the machine, and 1*s.* 1¼*d.* by manual labor.

English and American Railways.*—The London "Railway News" has some interesting comparisons of English and American railway returns, and in the matter of rolling stock and train earnings is surprised to find the American roads more economically run than the English. Taking four roads in each country, aggregating about 4000 miles, it is found that the American road has only ·33 of a locomotive and 6·72 freight cars per mile, while the English has ·93 of a locomotive and 28·83 cars. The New York Central, with a heavier traffic than the London and North Western, has half the locomotives per mile. The English refuse to believe that the superior size and strength of American locomotives account fully for this difference. The earnings, for instance, of an American locomotive are 70 per cent. more than those of an English, and the entire rolling stock, which in England barely pays for itself in a year, in this country pays for itself and 65 per cent. more. The "News" also discovers that, while passenger fares are 30 per cent. lower than in England, the earnings per train here are 4 per cent. more, and on freight trains 15 per cent. more, than on the English roads.

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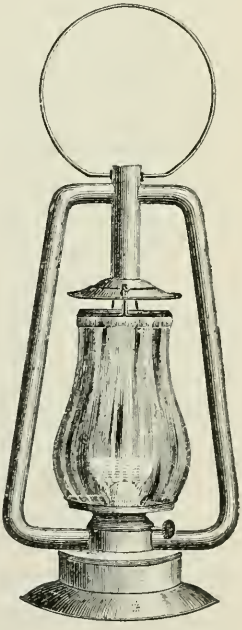
* Van Nostrand's Magazine, July, 1873.

The Irwin Tubular Lantern.—The Committee on Science and the Arts constituted by the Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, to whom was referred for examination John H. Irwin's lantern, respectfully submit the following report:

They have carefully examined the lantern submitted by the patentee, and also the several specifications of his letters patent, describing the several inventions involved in the construction and operation of said lantern, and find the construction and operation of the lantern to be as follows:

An oil pot forms the base of the lantern, in the top of which is inserted a flat-wick tube, with a windlass for raising or lowering the wick, and a dome, having a slot, through which the flame rises. Thus far as described it resembles an ordinary coal-oil lamp, with the chimney removed.



The space below the dome is enclosed, so as to exclude any access of air, excepting what may reach it through the two tubes, which, rising symmetrically from the two sides of the enclosure around the wick tube, unite and terminate in an inverted funnel.

Above the flame a swinging bail, attached to the top of the air-tubes, serves as a handle, and a globe of such size as not to be operative as a chimney is supported on a perforated plate resting on the top of the enclosed box under the dome, and extends upwards to within a short distance of the mouth of the inverted funnel, where it is held securely in position by a spring.

Around the top of the wick-tube is a small flange, projecting obliquely upwards. The wick-tube is fitted by a tapering slip joint into the top of the oil pot, and is centered in the dome by a spider or frame, secured near its upper end, fitting the interior of the dome.

The inverted funnel is of such diameter as to overhang the upper edge of the globe.

The operation of this lantern is as follows:

The oil pot being filled, and the wick adjusted and lighted, a current of air rises around and above the flame; a portion of this current enters the funnel, and is cooled, and conducted by the pipes to the enclosed space under the dome, where it is prevented by the oblique flange on the wick-tube from impinging directly upon the wick, where it might check the formation of combustible vapors or gases thrown against the interior of the dome, whence it is deflected against the flame, and issues in a current or stream, enclosing the flame and sustaining the combustion of the oil vapors and gases.

The flame does not burn by contact with air rising directly into the globe through the perforated plate, but is organized and sustained entirely in the envelope or stream of air brought down by the tubes from the funnel, and projected through the slot in the dome.

It would appear that a separation of the carbonic acid takes place from the rising current in the globe in consequence of its greater specific gravity, and upon reaching the upper rim of the globe, it there overflows and escapes. The products of combustion are discharged through the space between the globe and the funnel.

The function of the globe is merely to shelter the flame from lateral draft of air, and it does not operate as a chimney, but remains cool while the lamp is burning. The lamp, so long as there is no atmospheric disturbance, burns with a clear flame when the globe is removed. When the supply of air to the burner, through the inverted funnel and tubes, is interrupted, the flame is extinguished. This takes place whenever the lantern is overturned, or when anything is interposed between the flame and the funnel, and is a feature of safety, so far as the Committee is aware, not found in other lanterns.

When the lantern is swung to and fro by the bail, the centrifugal force of air in the tubes accelerates the flow of air to the flame, and brightens the flame.

The Committee find that when made in the proportions of the lantern exhibited, a clear, steady, and reliable light is produced without using a chimney, and that the lantern cannot be extinguished by the wind; and, further, that the principle of its operation is, so far as the knowledge of the Committee extends, novel, and the utility of the invention so obvious as to be appreciated on simple inspection, which facts your Committee think fairly establish its claim to the Scott Legacy Premium, the award of which to Mr. Irwin your Committee respectfully recommend.

WILLIAM H. WAHL, S. LLOYD WIEGAND, ISAAC NORRIS, M.D.

American Association for the Advancement of Science.—The twenty-second annual meeting of the American Association for the Advancement of Science will be held in Portland, Maine, commencing August 26th, under the Presidency of Prof. Joseph Lovering, of Massachusetts.

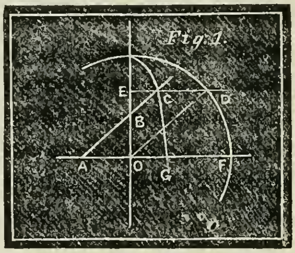
The St. Gothard Tunnel.—It may be of interest to note that the period prescribed for the execution of this great work is eight years, dating from October 1st, 1872. The contractor, M. Favre, has agreed to be fined $1000 per day for every day's delay. On the other hand, if he can open the tunnel in less than the time indicated, he is to receive a premium of $1000 per day.

A New Engine.—A new motor has recently been patented in this country, the operation of which is as follows: Oil is sprayed into the cylinder behind the piston, and, being mixed with air, is ignited at the proper time by an electric attachment. The consequent expansion drives the piston forward, the momentum of the fly-wheel returning it to its former position. An ejector supplies the oil from the tank to the sprayer, the ejector being connected to a piston blower driven by a crank attached to the main shaft.

The American Paper Trade.—During the year 1872 there were in operation in the United States 812 paper mills, owned by 705 firms, and of an estimated value of over $35,000,000. In addition to this actual value of mill property there is to be added the usual working capital, twenty-two and a half per cent. of the value of the mills, thus making the total capital invested in paper-making throughout the country about $43,500,000.

The mills employ 13,420 male and 7,700 female hands, besides 922 children, or a total of 22,042 laborers, whose wages amount yearly to the large sum of nearly $10,000,000. Their product amounted last year to 317,387 tons, valued at $66,475,825. The total number of engines running is 3,293, besides 299 Fourdrinier and 689 cylinder machines.*

The Trammel in General.—By William C. Cleveland, *Prof. of Civil Engineering in Cornell University.*—The well-known instrument for drawing the ellipse called the trammel has for its basis the kinematic principle that, *if two points of a right line move one in each of two right lines that intersect at right angles, every point of the moving line describes an ellipse.* That is (Fig. 1), two perpendicular lines meeting at O being directrices for the motion of A B, the path of any point, C, will be an ellipse.



The proof is as follows :

Describe a circle about O with a radius, OD = A C, and draw D C E perpendicular to O B.

The triangles B C E and O D E are similar, and give

$$\frac{CE}{DE} = \frac{BC}{OD} = \frac{BC}{AC} = \frac{OG}{OF} = \textit{constant};$$

a well-known property of the ellipse, easily made evident by taking the shadow of a circle upon a plane through its centre, the rays of light being parallel to each other and perpendicular to the intersection of the two planes ; therefore C moves in an ellipse of which O is the centre.

Mr. Edward W. Hyde, my assistant, having made an analytical investigation and model of the warped surface generated by moving a right line upon two other right lines perpendicular to each other, but not intersecting, in such a manner that two of its points remain one on each of the directrices, the following general geometric solution suggested itself to me :

If a circle roll inside another circle of twice its diameter, the path of each point of the rolling curve will be a diameter of the fixed circle. (Fig. 2.)

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* Paper Trade Journal.

In every position the rolling circle contains the centre of the fixed circle, and the radius, O A, to the point of contact, is a diameter of the rolling circle.

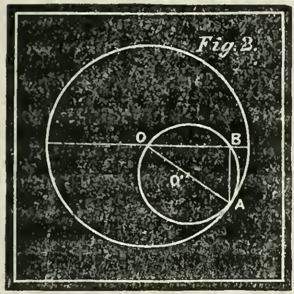


Fig. 2.

The point of contact, A, is the *instantaneous centre of rotation*, so that the path of B is perpendicular to A B ; but, A O being a diameter, O B is perpendicular to A B ; hence the motion of B is always toward or from the centre, O, and its path a diameter of the fixed circle.

Considering the motion of the diameter, O C, of the rolling circle (Fig. 3), O moves in the right line, A B, while C moves in the right line, C D, perpendicular to A B, therefore, by the principle of the trammel, every point of the indefinite right line, O C, describes an ellipse.

This being true for every diameter, it is true for every point rigidly connected with the rolling circle, either in its plane or out of it. Hence every point of the right line O N describes an ellipse.

But the point, N, moves on the diameter, O N, or a parallel above it, while O moves on A B.

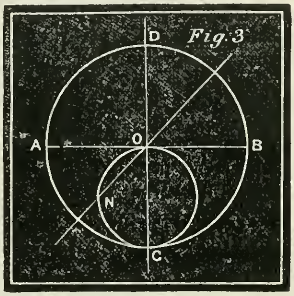


Fig. 3

Therefore, in general, *when two points of a right line move one on each of any two right lines, anywhere in space, intersecting or not, every point of the moving line describes an ellipse* in a plane parallel to the two directrices, the centre of each orbit being on the line intersecting the two directrices perpendicularly.

And, again, *if two points of a solid move one on each of any two right lines in space, any other point of the body being constrained to move in a plane parallel to the two lines, the orbit of each point of the body will be an ellipse* parallel to this plane, and having its centre on the right line intersected perpendicularly by all the directrices.

Ithaca, New York, December 2d, 1872.

Apparatus for Testing Petroleum Oils.—An apparatus for the purpose of testing the inflammability of petroleum oils destined for lighting purposes, designed by M. Granier, is thus described :

A small cylindrical receiver of metal is closed by a movable lid, provided with a circular aperture in its centre. This receiver is filled to two-thirds its volume with the oil to be tested, so that there remains between the lid and the surface of the oil an air space, into which the inflammable vapors given off by the oil may diffuse. A tube, soldered to the bottom of the receiver, holds a wick, the upper extremity of which is in the middle of the aperture in the lid, whilst a thermometer plunged in the oil gives its temperature. To make a test, the oil is poured into the receiver to the height required, the wick is saturated with it and lighted. The oil of the wick burning heats the oil till the temperature is reached at which inflammable vapors are given off. A slight explosion then follows, the light is extinguished and the degree on the thermometer is read off.

There are several points of doubt concerning the accuracy of the apparatus, which may or may not be well grounded. It would appear from the description that the flame of the wick remains constantly burning in proximity to the surface of the oil, so that it would be heated from the surface downwards, and not the reverse, which is the natural process. In consequence of this, too, the surface layer of oil would be constantly hotter than those below it, and the thermometer with bulb immersed in the oil would not accurately indicate the flashing or burning temperature.

In addition to this it does not appear that the heating of the oil can be conducted with the degree of slowness which one can command with the water-bath, as it is generally employed—a condition which, as all who are familiar with the subject of testing oils are aware, is of prime importance if grave errors are to be avoided. On the whole, if the description given of the Granier apparatus is correct, it is difficult to see any points of advantage in it, and not difficult to find many faults.

The Preparations for the Centennial Exhibition at Philadelphia in 1876 are gradually maturing, and the work of arrangement intrusted to the several committees is progressing. The executive commissioner, Prof. Blake, is at present at Vienna, making personal observation of the arrangement and conduct of that great display. He had carefully investigated the Paris exposition of 1867, as shown by his work upon it; and such experience is imperatively demanded, to avoid the blunders and mistakes of previous efforts. The commission is now in daily sittings at their rooms, Walnut street near Ninth, where they have employed two secretaries and three heads of bureaus, each of whom is entrusted with the management of some specialty. The necessity of pushing forward as rapidly as possible the preparations for the exhibition buildings is fully recognized. The location of the grounds in the park has already been selected, and plans for effecting the drainage, shading, and general decoration of the same, will be put into operation almost immediately. The statement is made that the committee on plans and architecture have decided to make use of four buildings—a central, main building, to be devoted to general exhibition purposes, and separate structures to contain the departments of fine arts, of machinery, and of horticulture. It is further stated that the appointment of the architect will be thrown open to public competition, and that all architects will be invited to contribute plans; the authors of the ten most approved designs to each receive a prize of $1000. The decision upon the successful plan will be made about July.

The Diamond and Graphite.—An important paper "On the Behavior of the Diamond and Graphite when Heated," by G. Rose, has recently been published.

From various experiments in which the diamond and graphite were burned together in a muffle, the author draws the conclusion that the leafy graphite is much less combustible than the diamond, while the solid graphite is more easily burned. He found, also, that when air is excluded the diamond may be subjected to a temperature at which pig-iron will melt, and to the strongest heat obtainable in a porcelain furnace, without being in the least affected; but at a higher temperature it is gradually transformed into graphite.

Upon the same subject, Mr. Spence, of Manchester, has made experiments which seem to prove that under certain conditions the diamond is combustible at a much lower temperature than has formerly been supposed. A South African diamond, of the size of a small pea, coated with refractory clay, was placed in a crucible with a mixture of soda and hydrate of lime, and then heated in a muffle for three days and three nights. On opening the mass it was found that the diamond had entirely disappeared, although the heat had never exceeded a cherry-red.

Editorial Correspondence.

Editor of Journal of Franklin Institute:

Dear Sir:—The conveniences for work in both physical and chemical laboratories are multiplying. Among the best furnished institutions, as, for instance, the Stevens Institute at Hoboken, hot water, cold water, steam, oxygen, hydrogen, illuminating gas and electricity are furnished to hand by merely turning a stop-cock or a button, but the means for producing a vacuum so readily are not to be had, though quite as much needed as some of the above mentioned things.

The air pump has always had to do double work, exhausting muscle as well as the bell glass. Sprengel, Geissler, Bunsen and Draper have each contributed a modification of one idea, to lessen the labor required to produce a vacuum, and I am sure that every one who has used their inventions has felt duly grateful, yet each of these appliances requires renewed adjustment each time it is used.

This has led me to think of a plan for having a *constant vacuum*, that shall be available on as short notice as a gas jet. Let a *vacuum tank* (misnomer or not!) be constructed with a capacity of a hundred gallons or more, which shall be kept exhausted by the Bunsen filter pump in constant action. Pipes may run from the tank to the various rooms where experimentation goes on, and connections made with rubber tube to the table where it is convenient to work. A stop-cock would be all between the vessel and a vacuum sufficiently good for most of the wants in physical or chemical experimentation. A barometer tube could be connected with the end of the pipe in each room, that would indicate, at a glance, the available exhaustion. Supposing that a better vacuum is needed sometimes, it will only be necessary to supplement with a Spengel or some other form, which is done now with the larger air pumps. It seems to me to be possible to construct a wooden tank that should furnish a vacuum balanced by less than one-tenth of an inch of mercury. I throw out this suggestion in the hope that, if it is thought practicable, it may be tried in some laboratory in the country.

Yours truly,

A. E. Dolbear.

Bethany College, Bethany, W. Va., July 19th, 1873.

Civil and Mechanical Engineering.

THE CONSTRUCTION OF IRON SHIPS.

(A paper read before the Franklin Institute.)

BY SAMUEL HOLMES.

(Continued from page 30.)

In the year 1853 it was proposed to build in England a steamer that would be a real Leviathan in size, and two eminent men, Mr. Brunel and Mr. John Scott Russell, took the matter in hand. The result is, the Great Eastern, of 22,791 tons, is now afloat, and doing good service as a cable ship. The proposition to build so enormous a vessel set mechanical minds thinking about the construction of iron ships, and it was apparent to the two engineers I have named that the transverse framing system was bad, and ill suited to iron vessels of length. Accordingly they severed at a blow their connection with it, and struck out anew by turning their frames around, and running them fore and aft, thus heralding in the system of longitudinal framing and constructing the strongest merchant ship afloat. John Scott Russell afterwards built the Annette, a vessel of 600 tons, and describes her arrangements as follows:

"1st. To divide the ship by as many transverse water-tight iron bulkheads as the practical use of the ship will admit. I like to have at least one bulkhead for every breadth of the ship in her length. In a ship eight breadths to her length, I wish to have at least eight transverse bulkheads.

"2d. I have between these bulkheads what I call partial bulkheads, or the outer line of a complete bulkhead with the centre part omitted, so as to form a kind of continuous girder running transversely all round the ship, and not interfering with storage.

"3d. I run from bulkhead to bulkhead longitudinal iron beams or stringers, one along the centre of every plate of the skin, so giving each strake of plates the continuous strength of an iron beam, one portion placed at right angles to another. This longitudinal forms one continuous scarph across all the built joints of the plates, hitherto their weakest part, and adds also to the strength of the rivets of the joint the help of a line of rivets and angle iron along the centre of the plate. These longitudinals and skin are therefore one.

"4th. What remains over after this is done of the superfluous iron formerly used in ribs, I make into a continuous iron deck, mainly carried by the bulkheads and by longitudinals under it, and I believe this iron is infinitely better applied in a deck than in ribs fastened to the skin."

The strength of the two systems, with the same weight of iron used in each, sums up in favor of longitudinal framing, in proportion as 650 : 520, or 5 to 10, equal to 25 per cent.

Mr. Jensen, of Dantzic, in a paper on Comparative Merits of the Longitudinal and Vertical Systems of Iron Ship Building, states that in a ship 600 tons burden, the gain in weight, on a similar ship built to Lloyd's rules, was 7 per cent. and the gain in strength 10 per ct., and that if the plating had been made as thick as is required by the rules for a vessel of the same tonnage, the gain in weight would have been 3 per cent. and the gain in strength 18 per cent. on a ship intended to occupy the highest class.

Another system of construction has been tried, which amalgamates the longitudinal and transverse systems. This has been carried out in the Indian troopships, where we find the longitudinal system of framing worked in the bottom, and the vertical system worked along the sides. This arrangement ranks considerably above the transverse system, as generally carried out in the mercantile marine, in point of strength, and also has the advantage of a saving in cost. This saving, as represented, by weight amounts to 150 tons iron, in vessels of the respective classes to which these troop-ships belong, which taken at a percentage amounts to 4½ per cent.

An estimate of my own, published in the "Nautical Gazette," for a 500 tons vessel, built on the longitudinal system, shows a capable saving of 7½ per cent. on total iron, 9½ per cent. on total labor, and 10½ per cent. on coal.

As we have reviewed the transversely framed ship and pointed out its shortcomings, we will now briefly comparatively consider, with a few practical remarks, the two systems, in structure, material and labor, and endeavor to represent more exactly where and how the longitudinal system has the advantage. Supposing the longitudinal ship to be rivetted is recognizing the fact that the shell is the strength of ship; first we have a saving of material of shell in direction of likely fracture, that is, in the direction of girth of ships; for, instead of having the shell holed all round, with only a space of six inches between holes, by running the frames fore and aft we have the holes the distance of the frames, or about two feet apart, thus giving only one-fourth the number of holes round the vessel. Again: at the bulkheads, which I have already shown to have double the number of holes that the rest of framing has, or holes every three inches apart, I propose in the longitudinal ship to give her no more holes here than in any other part of structure, by carrying the bulkheads *entirely* by a system of bracket knees, fitted at each longitudinal frame, thus giving out strength to the shell through the framing rather than reducing it one-fourth, as I have shown hitherto to have been the custom.

That the bulkheads may be water-tight, I propose to either bolt solid wood at each side, passing all round vessel's section, and caulk the edges with oakum, or build partial boxes on bulkheads, to be filled with cement, allowing the cement to harden against the bulkhead and shell of ship.

In alluding to the labor on the transverse frames, I may at once say they are *prodigal in cost*, as well as inefficient in structural strength. I have already shown they are composed of three parts, represented by five pieces, namely, two bars for an angle iron frame, a floor plate, and two bars for an angle iron reverse frame. All have to be furnaced, then bent when hot, and beveled. When cold they have to be set to exact line on body board, then spread out to be bolted together, and finally rivetted ; each piece having thus about five operations to go through, entailing the employment of a great many men, and a great waste of time, for instance, the waiting about 20 minutes by six men, five times each frame, for the angle irons and plate to heat, and where there is much bevel on a bar an extra heat has to be given each bar in addition. How different with longitudinal framing! and yet more so with the vessel I have designed and have yet to describe.

In the longitudinally framed ships, firstly, the iron is being used in the structure so as to give out the greatest strength, and, secondly, the cost is reduced to near a minimum.

The curves in the direction of a longitudinal frame are very easy, so that the frame can be bent in its cold state, and can be formed of but one section of iron, in place of the number of sections as in present practice, thus saving the vertical sides of two angle irons, or a whole angle iron, and two rows of rivets across floors, and one up the side at each transverse frame in ship. The longitudinal frame can be bent cold, as stated, and twisted so as to bring the frame at right angles to the shell all fore and aft, thus avoiding destroying the iron by beveling. This can be done by a machine I have invented and patented for the purpose. The machine will record on a dial the exact amount of twist put in the bar, so by adjusting the dial to the twist required, the bar can travel through the machine and finish with the necessary twist given it. The bending is done with as great simplicity, so that with one set of men I could bend and twist the same length of longitudinal frame that there is in a transverse frame, thus finishing the part, ready for going to its berth, in less time than it takes to heat one bar of the outer angle iron alone of an ordinary ship's frame; or, in other words, one set of men could bend and twist the whole of a ship's framing on the longitudinal system quicker than the outer angle irons for the framing of a transversely framed ship could be bent, without mentioning the after-setting, also bending and setting reverse frames, the bending floor-plates, bolting all together, and riveting up, which compares as extra, waste and inefficiency.

We here save material, save labor, save time. Another advantage of longitudinal framing is that the longitudinal keelsons and wash plates employed in the transversely framed ship are dispensed with, thus saving material and labor, the frames themselves doing the work of keelsons. It is true transverse strength has to be given, but this is only requisite amidships, and does not put in as much iron as we take out. Longitudinal framing gives a *stronger bow to the ship*, as the frames come closer together the nearer you approach the ends, and finally unite with a breasthook, which is a point of structural strength requisite in American ships, for the winter's experience teaches the difficulty of winter navigation. While longitudinal framing protects and strengthens the bow, it also greatly assists the stern, by giving an increased lateral strength to resist the vibration caused by the screw propeller. We may summarize the structural advantages of longitudinal framing as increased strength of bow and stern, increased longitudinal strength, increased strength of frame by twisting instead of beveling (allowing the frame thus always to sit at right angles to the shell plating), a better distribution of the strength given by bulkheads, support and connection given the shell by each frame crossing the butts (the weakest place), the prevention to wash of bilge water across the bottom as the ship rolls, with the consequent likelihood of rivet-heads and plating being worn down by debris.

The economic advantages lie in the frames being of one section of iron, of their being bent and twisted cold and by machinery, the whole labor being done at one handling; of there being no riveting to do beyond the connection of the butts, and no yard space required to spread the frames on ground, as they go direct from machine to their berths—the whole resulting in a saving of time, material and workmanship.

The degrees of comparison we are familiar with as three in number, and whatever opinion you may so far have formed of iron ship construction, I consider that the positive and comparative only have been touched. Positively, the present ship is transversely framed. Comparatively, the longitudinally framed ship is much superior to the transversely framed ship, being stronger and cheaper. But the superlative ship must be *welded*, thus saving the punching away of material, and keeping up the original strength of material as absolute strength of structure all throughout.

The process of uniting iron by means of welding it together traces back to about pre-historic times, so it it is out of reach of man to claim originality in discovery of principle here traceable; but originality is claimed by me for the discovery of means to apply the principle of welding to ships, for I now can weld up a ship in entirety by *machinery*.

Boilers have been welded successfully, but at great trouble and expense, through inappropriate methods being adopted. My late grandfather, Mr. Timothy Hackworth, the inventor of blast-pipe and builder of first locomotive that ever beat horses, had the honor of constructing the first welded boiler at his establishment in 1849, in which year the boiler of passenger engine "Sanspareil" was welded.

Tubes are being welded every day in this city, and at the yard of John Roach & Co. boiler flues of large diameter are welded, which shows the bent of present mechanical desires and necessities. Suggestions that may lead to revolutionizing changes in the iron mechanical structures of the world, are thus to be daily gained, and when once possessed, the impelling force of duty to yourself, your neighbor, duty to the State, should constrain the individual to act his part with earnestness. It would be superfluous and a supererogation to attempt to show a mechanical man that a weld is superior to a rivetted joint, and a ship owner would tell me that it was unnecessary to prove to him that a whole plate was stronger than two plates indifferently connected. The mode of forming a weld is matter of considerable importance, and I here enter a protest against the main strength and stupidity method of battering all the nature out of the material by a succession of blows. Hydraulic welding is a step in the right direction, for we here get weight or pressure without a blow, and can form a perfect weld. The method I introduce must be explained further on, as I must now call your attention to my combined shell and frame, welded ship.

The interest in iron ship building, and absolute necessity for something to be done in reducing its cost, has caused me to give my closest attention and best thoughts to this subject, which I have been familiar with all my life and have solely practiced since my business career commenced. As soon as I had mastered the situation here, I turned my attention to longitudinal framing, as an improvement in iron ship construction, and have advanced by degrees with three points full in view, namely, structural strength, section of iron, and machinery instead of labor. Discarding transverse framing altogether, as a mechanical abortion, I took refuge on the longitudinally framed ship, and designed and patented a machine for bending and twisting the frames, as already alluded to; but I was still dissatisfied, as the method of fastening compelled the introduction of necessary yet useless weight. I allude to the requirement of packing iron, which is necessitated by the frame passing over the butt straps, so that between strap and strap there is an interstice equal to the length of plate, thickness of straps and breadth of frame, which must be filled in solid, or the frame must be joggled over the strap. The latter arrangement, however, gives too much labor; so the packing difficulty must otherwise be got over. Putting the straps outside suggested itself, but appearance must be kept up; besides, we should be adding resistance by an uneven surface. Then the suggestion of butting the edges of plating, and making the longitudinal frame act as straps was considered, but this gives too much riveting; besides it throws the frames wider apart than I desired; so the difficulty still presented itself. I thought over the matter by night and day, and finally settled it must be accomplished by *welding*, and quickly realized the other benefits embraced by this mode of fastening, but was as quickly enveloped in the darkness of practical difficulties surrounding its accomplishment. Were there not practical difficulties of an apparently overwhelming nature, welded ships would long ago have been a reality. The difficulties to contend with were, first, to get a welding heat on a ship; second, to discover a method of forming the weld; and, third, and perhaps the worst difficulty of all, was to prevent the stretching or buckling of plate, which is a practical difficulty that would make welding a failure were it not met; for, supposing two plates on a ship's side, bolted in position, with the requisite amount of scarphled lap' the thickness here, of course, is greater than single thickness of plate ; so when the weld is made, and the scarph drawn down to near ordinary thickness of material, the thickness has then changed shape, and the area is made up by more surface being given it, which increased surface results in a buckle, and before the welding has proceeded far along the edge, the buckling and twisting will have increased until the two plates are imitating a pair of scissors, by either opening apart or closing over each other, thus foiling your attempt and wearing you out with everlasting aggravation and failure.

This has been the stopping point together with the mode of making the weld, and I here claim originality of device, for I have dispensed with hammering or forming the weld by labor that takes the nature out of the material, *and invented a machine to do the work scientifically.* I have also overcome the buckling difficulty, by *designing an entirely novel and original ship.* The novelty and originality of my vessel lies in the *plating and frame being formed of one and the same piece of iron.* This is accomplished by using for the shell iron with a flange at each side, such as is known as Channel iron. One flange accordingly comes against the other, thus bringing together two narrow strips of iron, which have but to be brought to a welding heat and the operation of a squeeze applied and the weld is complete. You will, in less time than it has taken me to utter this, have comprehended how I dispel the buckling difficulty, for the extra thickness before the weld is made has plenty of room to spread out in surface or breadth of flange ; for, owing to the flange being narrow, and the pressure covering its whole breadth, it gives on the edge instead of buckling, as is unpreventable in a broad plate with a blow or a pressure coming upon a narrow strip of it.

My method of forming the weld is of the simplest description. It is done by a blow-pipe fire preceding a pair of rollers, as illustrated by drawing. The fire I propose to make about two feet long, and convey the blast to it by india-rubber tubes connected to a main blast box, running, under ground, the full length of building slip. I enter one blast at the fore part of fire, so as to heat up the iron ; then, at after part of fire, I throw a blow-pipe flame on to the iron—which brings it to a welding heat. That is no sooner arrived at than I travel the rollers over the place, thus squeezing the material together and forming a perfect weld without hurting the material in the least.

My patent welding machine is composed of a piece of flanged plate iron, acting as a frame, at the lower part of which are a couple of metal blocks, riveted on, through which the spindle of lower roller passes and becomes a fixture. At the upper part of frame are two other metal blocks, through which the upper spindle passes. These blocks are confined by guides which give latitude to travel with a vertical motion, which is regulated by two screws, thus enabling the man in charge to fix the rolls at their requisite pitch to perform the work. The fire-box is connected to the back of frame by a hinge, which enables the fire to be swung away from the ship's side. There is also a slide attached, so that the fire-box, if necessary, can be pushed forward while still attached to frame of machine. The whole affair—machine and fire—is travelled forward on the welding flange by means of a ratchet, or handspike pulley (to save weight, fitted on the lower spindle), as rapidly as the welding heat is arrived at. That the fire may have full play upon the inside of flanges, I propose having the iron rolled at the mill to an acute angle instead of right angle, thus leaving the two surfaces open for the force of fire to play upon. The weight of machine is counteracted by a balance-weight on outside of ship, which is attached to machine by a chain passing over a pulley travelling on top of flanged plate, so that no unnecessary weight is brought on the heated flange. As soon as the right pitch of rollers is ascertained, I clamp them by a screw close to the rollers, so there may not be any spring to the spindles, and the iron be given a uniform thickness.

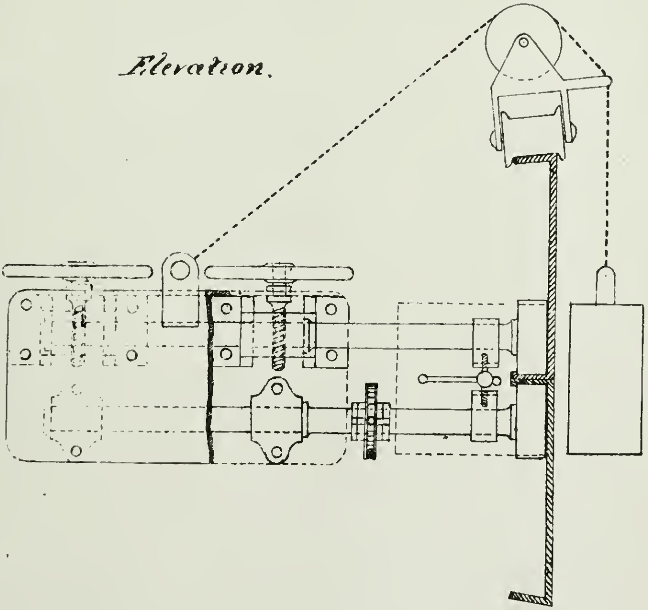
As a further remark, I must add that the method described is simple and practical, and is based upon the following propositions being satisfactorily replied to: Firstly. Can iron be brought to a welding heat? To which the reply is, Yes, it can, and is every day; thus practice being practical proof. Secondly. Is it necessary that the fire should be on the ground as a fixture? Certainly not; heat is not dependent upon such considerations. Thirdly. Can iron be welded? Yes, it can; every day's experience teaches the truth of it. Fourthly. Is a blow necessary to form a weld? No, it is not; weight or pressure is the requisite, whether as a blow or a squeeze, preference being given to the latter, as the former has a tendency to crystallize the iron and make it brittle. These propositions being satisfactorily settled leave the ground clear, and let those who have the courage and ability apply the principles to the furtherance of the mechanics of iron ship building.

The detail comparison of longitudinal strength between welded ships and transversely framed ships of 500 tons is as follows:

S. HOLMES

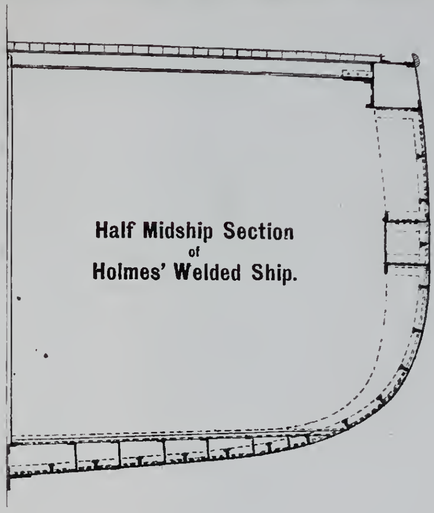
IMPROVEMENTS
IN
SHIP BUILDING.

Holmes' Welding Mac



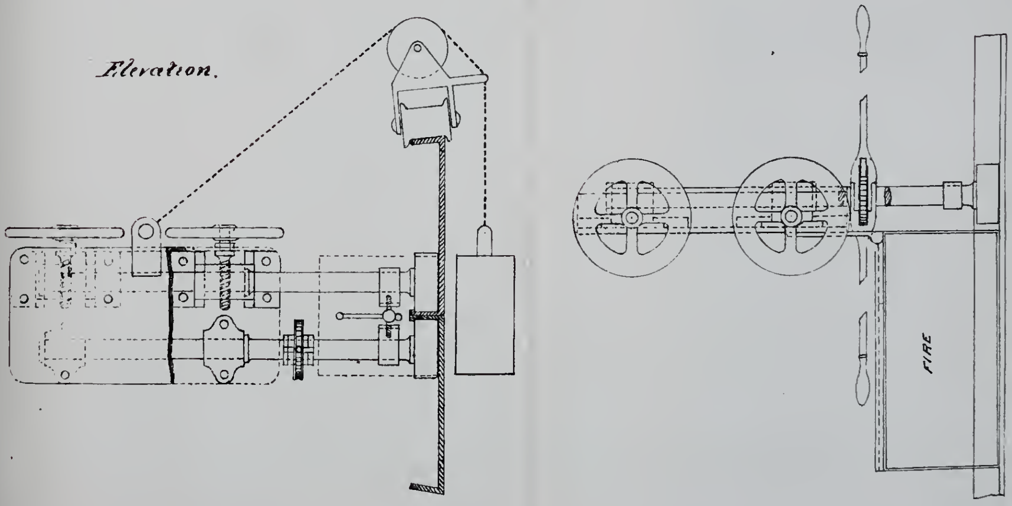
S. HOLMES

IMPROVEMENTS
IN
SHIP BUILDING.



Half Midship Section of Holmes' Welded Ship.

Holmes' Welding Machine.



Elevation.

Plan.

Transversely Framed Ship.	
Shell	374·00 sq. in.
Keelsons	51·00 “
Stringers and their Angles	86·00 “
Keel	16·75 “
	527·75 sq. in.

Welded Ship.	
Shell	346·00 sq. in.
Frames	102·00 “
Floors	74·00 “
Girders	187·00 “
Centre Keelsons	20·00 “
Keel Flange-plate	18·00 “
	747·00 sq. in.

Comparative strength, 747·00 : 527·75, or 41 per cent. in favor of Welded Ship.

As I only propose carrying these longitudinal floors along the straight parts of bottom, I think in most cases (where light draft is not a necessity) it is desirable and an improvement that they be outside the ship instead of inside, thus *effectually protecting* the bottom, greatly steadying the ship, and vastly increasing the capacity, while they add little extra resistance, for it is chiefly a resistance of friction. That the increased frictional resistance is small, I consider fully proved by the fact that 30 or 40 feet can be added to a ship's midship body, yet her original power will drive her at about her original speed. To show you the restriction upon rolling these outside floors would have, I will quote experiments made upon a model with bilge keels by W. J. Froude. The model was first heeled over and set oscillating without bilge keels; secondly, with a single keel on each side, 21 in. deep; thirdly, with a single keel each side, 36 in. deep; fourthly, with two keels on each side, 36 in. deep; and, fifthly, with a single keel on each side, 6 feet deep. The results were as follows:

	Number of double rolls before model was practically at rest.	Period of double roll (second).
No. 1 No bilge keels,	31½	1·77
“ 2 Single 21-inch bilge keel each side,	12½	1·9
“ 3 “ 36 “ “ “	8	1·9
“ 4 Two 36 “ “ “	5¾	1·92
“ 5 Single 72 “ “ “	4	1·99

These results demonstrate in favor of outside keels to reduce rolling, for the number of rolls decrease 87 per cent., while the period of double roll increases 12 per cent. Such would be the effect upon my ship, and as rolling strains the ship transversely, this greatly reduces the necessity for transverse strength.

This I have shown can be done, and now let those who are equally interested with myself put the shoulder to the wheel, and American iron ships will lead the world.

Before dealing with the matter of cost I shall further describe the ship which in other particulars differs with anything yet constructed. The frame, it will be seen, takes the course of a longitudinal frame, as advocated, and it is worthy of remark that the assistant strength the shell derives from it is at the exactly requisite spot, namely, the point of connection between one flanged plate and the next. The butts I also propose to make equally strong with the seam, by turning up or flanging in the end and welding, as I do the seam, which gives me transverse stiffening at each butt. The superior structural strength of the shell and framing is that the whole is one solid piece of iron, without a hole, and accordingly of the original strength of material, which, in comparison with a double rivetted ship (the present first-class ship), as I have already shown, is 30 per cent. stronger (the superiority of solid plate over rivetting), which result is proved by experiment. Again: through being longitudinal framed, she gains 41 per cent. without deducting punchings in transversely-framed ships in comparison of longitudinal strength as seen in detail, making a total of 71 per cent. increased strength over the present first-class ship.

The extra strength which I give the bottom is obtained by means of large angle irons welded between the flanges of frames having the wide flanges vertical, and acting as longitudinal floor plates or keelsons. Or, I believe a better way would be to use channel iron the same depth, and place it at the *centre of each plate,* so that the bottom would be double stayed—stayed by vertical flange of frame, and by this channel iron, or T iron—floor at a distance of nine inches apart, centre and centre. From the centre of ship out to the bilge I reduce these floors in depth by a fair taper.

I have already shown the connection between the side of a ship and the deck is the weakest place in iron ship construction, and as the present mode of putting in beams does little to alleviate the trouble, I introduce a box girder, which is one of the strongest forms to arrange iron, as it gives out strength longitudinally and transversely, precisely what is required at this particular spot. Accordingly, inway of decks, especially the upper deck, this girder takes its place and continues all fore and aft, between the ends of beams and sides of vessel. The beams are attached, as shown in sketch, to the inner side of girders, and thus have their strength diffused along the side of ship and not confined locally, as at present, and, as already shown. From this girder at under side to side of ship, I fit plate knees at stated intervals, so as to spread the strength of girder as much as possible, and when a girder is fitted at tween decks, I spread the strength by knees alternately at upper and under side. On the top of girder I fit a broad stringer plate, as in present practice, which gives still further attachment to the beam. My whole object is, as nearly as possible, to follow the practice of a successful general, and throw the heaviest metal at the weakest spot, and thus relieve places that can take care of themselves of superfluous strengthening. For instance, the bilges and the connections of sides and deck are so closely associated that a weakness at one point reflects upon the other, accordingly, by strengthening the attachment of sides and deck, I can dispense with much transverse strength at the bilges, as the curves in plates there give superior strength to this part, and the vessel is guarded sufficiently against the strains tending to collapse her like a parallel rule. The fastening of bulkheads I have already explained in the longitudinally framed ship; they are to be carried by knees and made tight as recorded.

Transverse strength I give liberally to the flat of bottom and flat of side, as these are the places tempted to buckle by pressure or stress. These transverse stiffeners I propose to run entirely round the vessel's section at midships; but forward and aft of this I shall confine them to the flat surfaces. On the side, I reduce the strengthening in proportion to shape of a buttock line, that is, deep vertical side, stiffeners amidships at stated intervals, shortening to nothing at ends. The bottom I propose to strengthen similarly, reducing the transverse fastenings in the shape of a water-line. All parts of the ship that are curved will take care of themselves, as the curve in the shell plates is a better diffused strength than can be given a flat plate by extra stiffening. The mode of securing this transverse strengthening is a point I carefully provided for, so that I avoid the evils now witnessed by the transverse frame. I connect my material to ship's skin through surface plates of considerable width, so that any holing that has to be done is not done at a material loss of sectional area. The beams I spread further apart, owing to the introduction of box girder, and I propose to pillar each beam. I adopt the solid stem and sternpost, but certainly discard the bar keel. Having thus given you a brief description of the construction of my proposed welded ship, and having shown the superior strength she possesses over anything ever yet built, I am pleased now to show up a clear record of reduced cost in comparison with any vessel yet constructed.

Many of you will doubtless have preceded me in arriving at this point, and could yourselves show with clearness the great saving I effect in cost, but others there may be who regard all talk of reducing the weight of material and keeping the strength of vessel up, or rather over what it was by 71 per cent., as moonshine. To these, if there are any, I would address a few earnest words. First, a great gain at a saving assuredly is the case; and, secondly, to make it clear, I call particular attention to the fact that the material discarded is principally material that is only requisite for the style of fastenings adopted. Discard rivetting and you discard quantities of iron, such as butt straps, packing, laps of plating, rivets, &c., &c., which are of no value to the structure, beyond being essential to rivetting. The items I shall now proceed to enumerate are positively an out and out saving, and though it is frequently said, oh! that is an estimate, we will divide it by two, you must understand these are hard and fast items there is no gainsaying.

Saving in Material in a vessel of 500 tons.

Butt Straps, ...	12 tons.
Packing, ...	6 "
Bulkhead Liners, ...	2 "
Plate Landings, . . .	12 "
Rivets, ...	17 "
Reverse Frames, . . .	13 "
Longitudinal Keelsons, . . .	19 "
Beams, ...	3 "
	84 tons.
Deduct additional weight for transverse strength and longitudinal girder, . .	24 "
	60 tons =

16·3 per cent. on the total weight in favor of the welded ship. The punchings I account for by pairing with the scrap, as they are more than balanced by lack of scrap the ordinary shell plating is necessitated to bear. The extra cost of proposed form of shell plating over ordinary shell plating, equal to one cent per pound, or 5·3 per cent., owing to the iron used being flange quality, instead of common, as now used. I have already explained I reduce in weight, thus avoiding the increased cost, while I preserve the strength through superior quality of iron.

Saving in Cost of Labor:

Transverse Frames, Reverse Bars, Floors, .	20·0 per cent.
Drilling, ...	2·8 " "
Caulking and Chipping, . . .	10·3 " "
Straps and Packing, . . .	3·9 " "
Countersinking, . . . - .	1·5 " "
Saving on total labor.	38·5 " "
Deduct work on extra Transverse Fastening and Box Girder, ...	3·2 " "
	35·3 " "

in favor of welded ship.

The saving thus stands 16·3 per cent. on iron and 35·3 per cent. on labor in favor of welded ship, and gain in strength of 71 per cent. We must also take account of 10½ per cent. saving of coal, as all the work is done with cold material, thus saving fuel required for furnace. The fuel for welding will balance the fuel for rivetting where the same fuel is used, but more suitable fuel is designed. The work on the frames, reverse bars and floors of a transversely-framed ship is entirely saved, for you will have observed I have the frame and shell plate in one section of iron, so that the work required to bend and twist the plating is bending and twisting the frame at the same time. I do all by special machinery, giving the required twist and set to the workmen from the mould loft floor. The labor on keelsons I do not deduct, as it balances the work on transverse strength, which I add. I also set the labor of welding against the labor of rivetting; but as the rows of rivets in seams; butts and frames exceed the seams to be welded, I consider my estimate more than on the safe side. There is one point I must yet call attention to, and that is the fact of the flanged plates used for plating being all of parallel breadths, and the ship herself having a greater girth at midship section than at the ends. The mode of procedure I propose, is to work from the deck and from the keel, and make up the difference of girth by stealing strakes, or a broad taper flanged plate at bilge, the flanging of which I do by machinery.

This method is practically illustrated by the model before you, which is made to scale, built of copper with sections of material as proposed. The parallel plates have this advantage, that they can be kept in stock, so the ordering of iron is greatly simplified. At present each plate is of different dimensions, that is, different taper, and accordingly has to be separately enumerated; but with the alteration the expression of 500 tons, or 1,000 tons of channel iron, a certain length, breadth and thickness, will bring to the yard the material required. The quality of the iron deserves more than a passing notice, and in this particular my ship will far surpass anything yet produced, as she is constructed of iron, flangeable in quality, and bearing an increased breaking strain to that formed by the common or boat iron now in general use. It is, perhaps, worthy of observation that the tendency of ship-building is towards steel, with view to economy—that is, to carry in cargo what is dispensed with in weight of hull—as soon as the manufacturers produce the material dependence can be placed upon.

This principle of economy is embraced by me and embodied in the vessel I have delineated. She is of superior iron, which has increased tenacity; accordingly I can reduce the weight, retain the strength and carry in cargo the reduction. Apart from this particular saving in shell, my ship of 500 tons will carry 60 tons more than any other vessel afloat at the same displacement and draft as already shown in detail. A summary of advantages I claim for my welded ship is as follows:

Increased strength,	71 per cent.
Increased safety owing to above extra strength, bottom protection, as described.	
Saving (material)	16·3 “
Saving (labor)	35·3 “
Total mean saving on these items	20·92 “
Increased capacity owing to floors being outside.	
Increased dead weight (cargo) carrying ability 10 per cent. Less time in building about 20 per cent.	

With the growth of the iron trade, we expect quicker supplies of iron, and these at a reduced cost. The breadth of iron I propose to use is 18 inches, which will give support to the plate the same as at present, for though the frames are now generally 21 inches apart, there is a 3-inch flange, which gives some support. At my last visit to the Phœnix Iron Works, I brought my ideas before the managers there, and they told me, though they do not now roll channel iron over 12 inches wide, yet they will, if required, put down rolls. In fact, they wish to help along iron ship-building, and are extending their premises vastly, that every facility may be possessed for turning out iron cheaply.

To give you some idea of what they are doing, and accordingly what we may expect from them, at present they have a new mill in hand, 900 feet long by 296 feet wide, at a cost of one million dollars. This will be erected with every known labor-saving convenience.

Some particulars of the iron trade are not out of place here. The manufacture of wrought and pig iron has doubled itself in ten years; last year added 20 per cent. Within eighteen months the manufacture of Bessemer steel will have doubled. 95,000 tons is now manufactured, and within two years 125,000 tons will be added. This great interest is spreading and spreading, and those who strive to oppose it or set the forest against the mine, will find they are striving against material that will crush them. Though it has taken iron ten years to double, the last year shows by its proportion five years will now do it; but as the percentage increases each year, it will more likely double in three years.

I should like to touch upon shipyard plant, but time won't allow. However, I must add, I reduce the expense of a yard materially by dispensing with much heavy machinery and, at present, necessary tools, yet do all the work by machinery. I also hoped to be able to treat upon the localities for the yards, but must curtail.

My theme has been iron ships, and for the reason my honest convictions embrace iron as the best material, but I rejoice to know ships are wanted. Tonnage is scarce, and those that can build the best, quickest and cheapest will come to the front. I have no fear as to who will win; perhaps it matters little. What I request is that we each have the same advantages allowed. Competition has and will quicken our wits to the benefit of the country, and what has been done in other branches of industry will be done in ship-building.

I have given prominence to reduction in labor, but let me not be misunderstood here. It is not my desire or presumption to attempt to pull down the bulwarks of the country or sully a Scripture truth which stands forth with grand prominence as an article of the American's creed, declaring in letters bright as the stars in the national flag, "The laborer is worthy of his hire." Let us continue an elevated remuneration to labor, and the brain will save the body. Expensive labor is not a matter to be groaned over; not a matter to be regretted, but a matter to be overcome. How do we progress? Is it by never encountering difficulty? No! Is it by Faith, Hope and Charity, as our pastors direct us to gain heaven? No! but these may be component parts of our system. Is it by scratching away with pencil or chalk, when a flash of thought will do the work? No! Do we progress by ease and indolence? No, no! this is rottenness, worse than the contents of a whited sepulchre. It is by hard work, by new devices, by head, and not merely hand. Our superior remuneration is our great advantage, and very little time—mark my words, very little time—will declare it so that all will understand the mystery of liberal wages and cheap mechanism.

It has thus been my pleasant duty to foreshadow what can be done to facilitate a return of progress and prosperity to American shipping, and this I do by a method I believe to be the only true and practical one there is. Bounties are dangerous; monopolies restrict private enterprise; subsidies cannot be depended upon. So we must go to the vessel herself, where much can be done. I find it cause of congratulation that these changes fall to be made in America. Here precedent does not, must not, sway. The trammels of old age do not encumber the mind as elsewhere. Here we are not "cribbed, cabined or confined" by any conservative institution to the utter smothering of what is good in the new ideas of genius or common sense. Let us act, then, at once, that we may perfect ourselves before others begin to stir; and, if we move with energy, I look forward to the time when not only the American model but the American structure will be copied by the world.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

A regular meeting of this Society was held at the rooms in New York, March 19, 1873.

Joseph Whitney, C. E., of Cambridge, Mass., presented the subject of "Leakages in Water Pipes," illustrated by specimens of defective water pipes from the Cambridge water works.

He desired to make a simple statement of his own operations and experiments. The great and growing increase in the consumption of water, is a matter of the first importance in the management of water works. Scarcely a report relating to water works is issued which does not refer to it, and, as something quite unaccountable, still no systematic effort is made to ascertain its cause.

Some years since his attention was called to the subject in Cambridge, where, for three years preceding, the water pressure had been growing less, thus causing much inconvenience and insecurity in case of fire. This was ascribed to the great number of users from one main, an eight inch pipe. In a particular house the water scarcely rose to the second story, at night or day. After inquiry, a series of observations were made with syphon pipe and pressure gauge, to determine the cause. These were made in the morning, when the consumption was nearly nothing, and in one case, by shutting off certain sections from the main, say a four or six inch pipe, a large leak was revealed where the pipe, laid in a street filled with oyster shells, had parted. In another case, when the gate was closed, the water in the syphon at once rose sixteen feet—equal to about two stories of an ordinary house—the pipe about 600 feet long and laid upon a much, was examined, and the leak found in a joint where the two parts had been entirely separated by a settlement of one section. These and other leaks, detected similarly, were closed, and thus, without any increase of size in the main, an additional head was secured of 35 feet, which gave a full supply to each house in that locality.

Observations were afterwards made upon the water in the reservoir in the night time, which showed still a leakage. By continued experiments upon the pipes throughout the city, nearly 200 leaks, of from 1000 to 2000 gallons each per hour, were found. The necessary repairs were made, and thereby the average daily consumption per head was reduced from 85 to 35 gallons, which is not more than one half that in most cities.

Leakage of this character may exist a long time without being known; thus, it may start when the water is first let on, and teh water find a passage through some blind channel into the sewer. It will not be seen at the surface unless thus upward and outward is the easiest course.

It is quite probable that this subject concerns other cities than Cambridge, and furnishes a satisfactory reason for the great increase in the consumption of water, and the corresponding growing demand for supply, which more or less embarrasses public authorities.

It is said that in the city of New York, the consumption is about one hundred million gallons per deim; if so, he was sure at least fifty million were wasted through unrecognized leaks into the sewers and surrounding rivers. In Boston, more than seventeen millions of gallons are supplied, where eight millions should suffice.

It is a fair presumption that one half these great amounts, being but waste, and its corresponding cost in the construction and operation of water works, may be saved. Surely, examination, complete and exhaustive, should be made, to determine whether this is presumption or fact.

Thomas F. Rowland, M. E., of Greenpoint, N. Y., presented a paper on the "Adaptation of Mechanical Power to the Work of Charging and Discharging Gas Retorts," illustrated by a large working model of machinery for the purpose; by which it is proposed to take the coal from a pocket outside of the retort house, size, mix, transport and deposit it in proper quantities in the retorts, and afterwards discharge therefrom the resulting coke into the coke-barrows.

The apparatus consists, first, of an iron car, which traverses the retort house in front of a bench, upon a railroad of twelve feet gauge, and carries the mechanism for charging and discharging; and, second, a series of buckets which, suspended from an overhead or "pendant railway," conveys coal to the charging apparatus.

The iron car, about fourteen feet square, is propelled by an engine and boiler placed upon it, which also drive the machinery carried. Midway on the car the meter is located, which receives the coal from the buckets and deposits it in the charger.

The meter is a horizontal cylinder divided longitudinally into three compartments or cavities, such that each will contain enough coal for one retort. It revolves intermittently at the base of a hopper or "coal pocket," which receives the coal from the buckets, each cavity therein being in turn filled with coal and emptied by discharge into shutes, severally in communication with the three scoops of the charger. These shutes are placed one above the other, and as the meter revolves, are automatically opened and closed, so that the coal is dis charged into each in succession. The edge of the meter cavities and of the throat of the "coal pocket" are armed with hard, sharp, steel blades, to cut or crush fragments of coal which, lodging between the surfaces, otherwise might clog the machine.

The "charger" is a carriage traversing the top of the car, transversely; its three scoops are placed one above the other at distances corresponding to the vertical measure between the retorts; they are D-shaped, like the retorts, and have moveable bottoms. When the scoops are filled, by a transverse movement of the carriage, they are thrust forward into the retorts; the motion being reversed, the bottoms, and then the scoops, are withdrawn, thereby the coal is deposited evenly over the retort, and the scoops made ready for another charge.

The "discharger" is a carriage similar to the "charger." The two are placed at opposite ends of the car, and the meter between them. By an automatic device, three hoes or rakes are simultaneously thrust into three retorts, dropped until they rest on the retort bottoms, and then withdrawn, whereby the coke is removed and discharged on to the retort-house floor, or into coke barrows.

One tier of retorts may be charged and the adjacent one discharged at the same time, and in a very brief time.

The "pendent railway" consists of two single parallel rails, ten feet apart, suspended from the retort house roof, over the railroad before mentioned, and connected at the ends by semi-circular rails, thus together forming an endless line, from which is suspended a series of coal buckets, attached to a flexible steel belt, by which they are separated, at uniform distances apart. The belt passes around horizontal drums, ten feet in diameter, and placed one at each end of and below the line, their vertical shafts being in the centre of the curved rails. One of these drums is an idler—the other, that at the receiving end, is in a tower outside of the retort-house. In its periphery are two openings, diametrically opposite, which, by two inclined shutes, are connected with a fixed cylindrical hopper or reservoir for coal above. The buckets are vertical cylinders with one half of the upper part cut away, so that when they are in contact with the drums, their acial planes coincide with the periphery. The space between the buckets on the belt is equal to one half the circumference of the drums.

When this apparatus is in motion, the buckets pass along the "pendent" railway; their openings are brought successively in contact with the openings of the drums, so that the coal conveyed by the inclined shutes from the reservoir, drops through them—the quantity being regulated by valves in the shutes, worked automatically.

The buckets have hinged bottoms to drop downward, and are opened when passing over the "coal pocket" on the car, at the will of the operator, by releasing a catch; they are mechanically closed just before reaching the drum, where they are filled.

The coal in the yard, after passing between sizing and mixing rolls, is lifted to the reservoir over the drum by elevators, similar to those used at Messrs. Hecker's flouring mills in New York.

The several parts of this apparatus can be worked independently, and thereby accommodated to the varying demands likely to be made upon it.

Chemistry, Physics, Technology, etc.

THE REDUCTION OF AURIFEROUS PYRITES BY DESULPHURIZATION AND AMALGAMATION.

Facts and Figures.

By Dr. Ira M. Phelps.

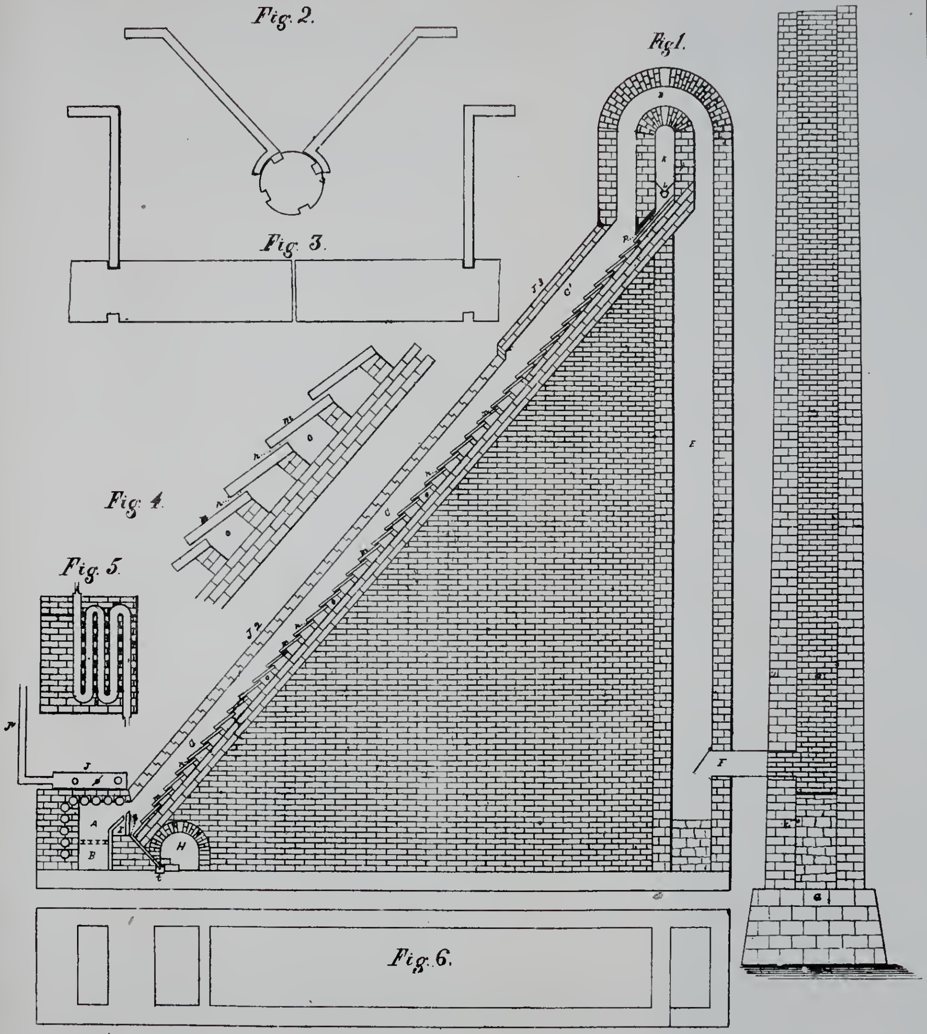
The reduction of gold-bearing iron pyrites by desulphurization and the abstraction of its precious metal or metals by amalgamation is an object of the highest metallurgical importance, as well as scientific interest.

The peculiar attractions of this process, and its promised superiority over all others, consist in its evident simplicity and cheapness, for by this method the sulphur contained in the ore furnishes a large portion of the fuel; it being compelled, in a great measure, to consume itself; and, secondly, in the inexpensive yet efficient chemicals made use of. Oxygen and mercury, the former obtained from the atmosphere without money and without price, and the latter secured against excessive loss by properly constructed amalgamators, are the only chemicals needed, except that furnished by the ore itself. Besides, it is a little gratifying to be able to seize upon this most troublesome element, sulphur (the cause of all the failures and disappointments), and compel it to do duty, not only in accomplishing its own destruction, but in effecting the release of the golden treasure it has so long and persistently guarded.

That a thorough desulphurization of the ore is a necessary prelude to amalgamation is a conceded fact, but right here has been and is the great difficulty, and so many failures have been made in trying to accomplish it, on a large scale, that not a few of the unsuccessful experimenters declare it an impossibility.

That the cause of all the failures has been *an insufficient supply of oxygen* can, we think, be proven to a mathematical demonstration; the enormous bulk of air necessary to supply it having never been even approximately estimated or conceived. But in addition to this there are three other conditions, to secure and maintain which is of vital importance, making four in all, viz.: *First.* A supply of oxygen sufficient to meet all the demands of oxidation. *Second.* A proper and timely regulation of the heat. *Third.* The constant agitation of the ore. *Fourth.* Sufficient time to perfect the chemical

PLATE. I.



Dr. Phelps' Oxidizing Furnace,

PHOTO. LITH. FROM TRACINGS BY A. DIDKES, 125 SOUTH FOURTH ST

changes involved. To enable the reader to comprehend the difficulties imposed by the first condition mentioned above, we will make an estimate of the quantity of air necessary to desulphurize twenty-four tons of pyrites daily.

Sulphur, as every chemist knows, when burned, consumes an amount of oxygen equal to its own weight; hence, if we can ascertain the number of pounds of sulphur contained in a ton of ore, we at the same time determine the quantity of oxygen necessary to effect its combustion.

This, of course, cannot be done with absolute correctness, for the reason that the ores, as delivered at the mills, are never chemically pure, but a sufficient approximation to the truth can be obtained to answer the purpose of illustration.

Iron pyrites, the most abundant and the richest, as well as the most refractory gold-bearing ore of the Rocky Mountain districts, is a bisulphide, consisting of two equivalents of sulphur and one of iron. Reduced to a per cent., it contains $53\frac{3}{10}$ of the former and $46\frac{7}{10}$ of the latter. But, as just remarked, this ore, as delivered at the mills ready for reduction, is never pure, but is generally combined with other sulphides, such as that of copper, zinc, lead, arsenic or antimony, each of which contains a less proportion of sulphur than the iron. In addition to these it is frequently mized with quartz and other gangues, containing little or no sulphur in their composition. Let us assume then, that the ore, ready for the metallurgist, contains twenty-five per cent., or 500 pounds of sulphur to the ton. Now if it be necessary to burn, *i e.*, *oxidize* this entire quantity, it follows that 500 pounds of oxygen will be required for the purpose; but, fortunately, such is not the case. One equivalent of the sulphur may be expelled by the action of heat alone, and without the aid of oxygen—a fact daily demonstrated in the process of obtaining the sulphur of commerce; a large portion of which is taken from non-auriferous pyrites, the identical bisulphide so richly impregnated with gold in many sections of the United States. In the process just alluded to, the air is carefully excluded from the furnace, in order to prevent the formation of sulphurous acid gas, but only one-half of the sulphur is driven off, and any amount of roasting, with the air excluded, fails to dislodge the remaining portion.

So in roasting auriferous pyrites, preparatory to amalgamation, it is found an easy matter to drive off fifty per cent. or more of the sulphur; but ore, only half desulphurized, is nearly as tenacious of its gold as the raw.

The fact appears to be that while one equivalent of the sulphur is easily expelled, the other is held in such close chemical combination with the iron, that heat alone, however intense and long continued, is insufficient to overcome the affinity, and oxygen must be introduced, in quantity at least equal to the weight of sulphur, in order to accomplish what the heat has failed to perform.

We have already supposed a ton of ore to contain 500 pounds of sulphur, and allowing that one-half may be driven off by heat alone, there will still remain 250 pounds in intimate combination with the iron, requiring 250 pounds of oxygen or 1,250 pounds of air for its combustion. A pound of air, at the level of the sea (under certain standard conditions of temperature and dryness), measures 13·29 cubic feet; but at the altitude of most mines, in the Rocky Mountain districts, a pound will measure at least fifteen cubic feet. On this hypothesis, 1,250 pounds will measure 18,750 feet, and this may be set down as the quantity required to burn out the sulphur in one ton of ore. But this is not the only demand made for oxygen, for the iron, as previously explained, must be thoroughly oxidized in order to be thoroughly desulphurized.

As the proportion of iron is a little less than that of sulphur, let us assume that 490 pounds is the average quantity to a ton of ore, the conversion of which into a peroxide will require 210 pounds of oxygen or 1,050 pounds of air, measuring 15,750 cubic feet.

From these data we are able to make the following statements:

Air required to oxidize the sulphur, . .	18,750	cubic	feet.
Air required to oxidize the iron, . .	15,750	"	"
Total air required for one ton of ore, . .	34,500	"	"
Twenty-four tons will therefore require .	828,000	"	"

This, be it remembered, is upon the hypothesis that every pound of oxygen, contained in this quantity of air, is used—no allowance having been made for loss or waste. In *practice*, however, only a small portion of the oxygen can be secured during its transit through the furnace, and an additional quantity of air, sufficient to make up the loss, must be transmitted, or another "failure" will reward the efforts of the disappointed and baffled metallurgist. Any person watching the operation of roasting ore in any of the furnaces now in use, will be convinced that not *one-tenth* of the oxygen transmitted is secured and appropriated during its transit.

Now if it be true, as the above facts and figures prove, that *all* the oxygen contained in 828,000 cubic feet of air is required, it follows, if only one-tenth is secured, that ten times the above quantity, or 8,280,000 feet will be required to perfect the work.

In order to assist our minds to comprehend this vast quantity, we will make one more estimate. Let us imagine this number of cubic feet to be extended in a single straight line; and when we ascertain it would form a body of air twelve inches square, *and* 1,568 *miles in length*, the thing begins to loom up in its truly giant proportions!

It may be urged that the water contained in the ore furnishes a large portion of the oxygen, and hence a less quantity of air is required. But it must be remembered that the above estimate is based upon the hypothesis that all the sulphur burned is converted into a dioxide (sulphurous acid gas); whereas, if aqueous vapor be present, a portion of it will be converted into the trioxide (sulphuric acid), which contains fifty per cent. more oxygen than the former; hence, if the water's quota of oxygen is thus disposed of, the first two eqs. must be furnished by the air as in the above estimate.

Enormous as this quantity is, it is probably far short of what is really required by many furnaces now in use, owing to the fact that the one great and essential feature of economy in the use of air is entirely ignored in their construction. The prevailing practice is to 'save' one pound of oxygen and suffer ten, twenty or more to escape, and after much labor and vexation of spirit, to wonder why the operation proved a failure! A far greater wonder would it have been had it proved a success.

A person attempting to melt a ton of pig iron by using only *one bushel* of coal, would be considered a fool or a lunatic, yet men of sense have been trying, for years, to accomplish a similar absurdity, by burning a ton of sulphur with one or two hundred pounds of oxygen; whereas, nothing less than ton for ton can accomplish the work. In one respect, such experiments have been uniformly successful; they have proven, to a demonstration, how the thing cannot be done.

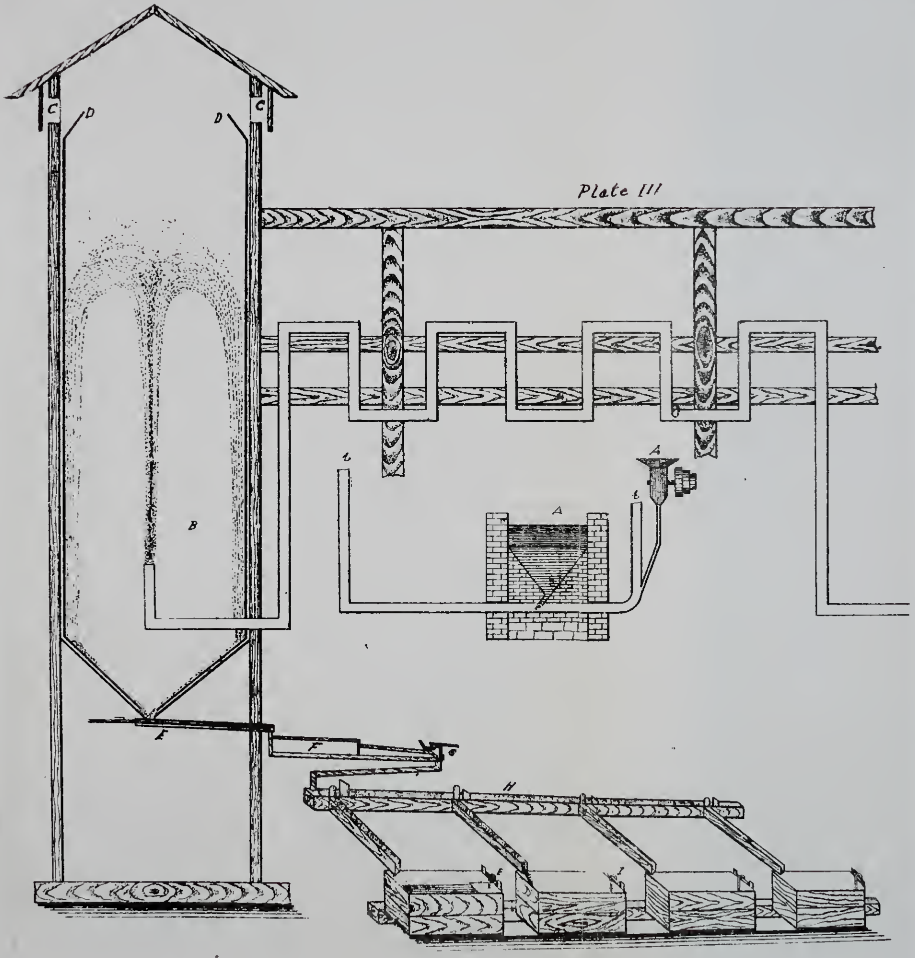
The second condition mentioned, viz., the proper and timely regulation of the heat, is all important. The great danger is the production of too intense a degree while a considerable portion of the sulphur yet remains, thereby causing a partial fusion or "slagging" of the ore. This is particularly liable to occur in those furnaces in which it is roasted in batches, and constant care and labor are required to heat the ore gradually, with constant stirring, in order to prevent the accident alluded to. This constant stirring (the third condition mentioned) is also necessary in order to expedite the operation, and experience has proven that to burn the ore *in suspension*, or while falling from one point to another, thus securing a free circulation of air between the burning particles, is not only by far the most expeditious, but the most successful in producing perfect and uniform results.

The fourth condition mentioned demands sufficient time to perfect the chemical changes involved in the operation. This will depend entirely upon the perfection of the conditions; that is, upon the more or less perfect adaptation of the means to the end; and, secondly, upon the degree of fineness to which the ore has been reduced. A ton of ore may be roasted in some furnaces for a month without being desulphurized. A revolving cylinder furnace will accomplish the work in ten or twelve hours, while it is claimed that the one herein described will desulphurize twenty-four tons in as many hours.

This may seem incredible to many persons having a practical knowledge of the business *as at present conducted*, but a little reflection, assisted by a few carefully conducted experiments, may remove all doubt. Thus, take the largest particle admitted into the furnace (less than half the size of a pin's head), and bring it under the oxydizing flame of a blowpipe; a very few seconds will be time sufficient to desulphurize and oxidize it.

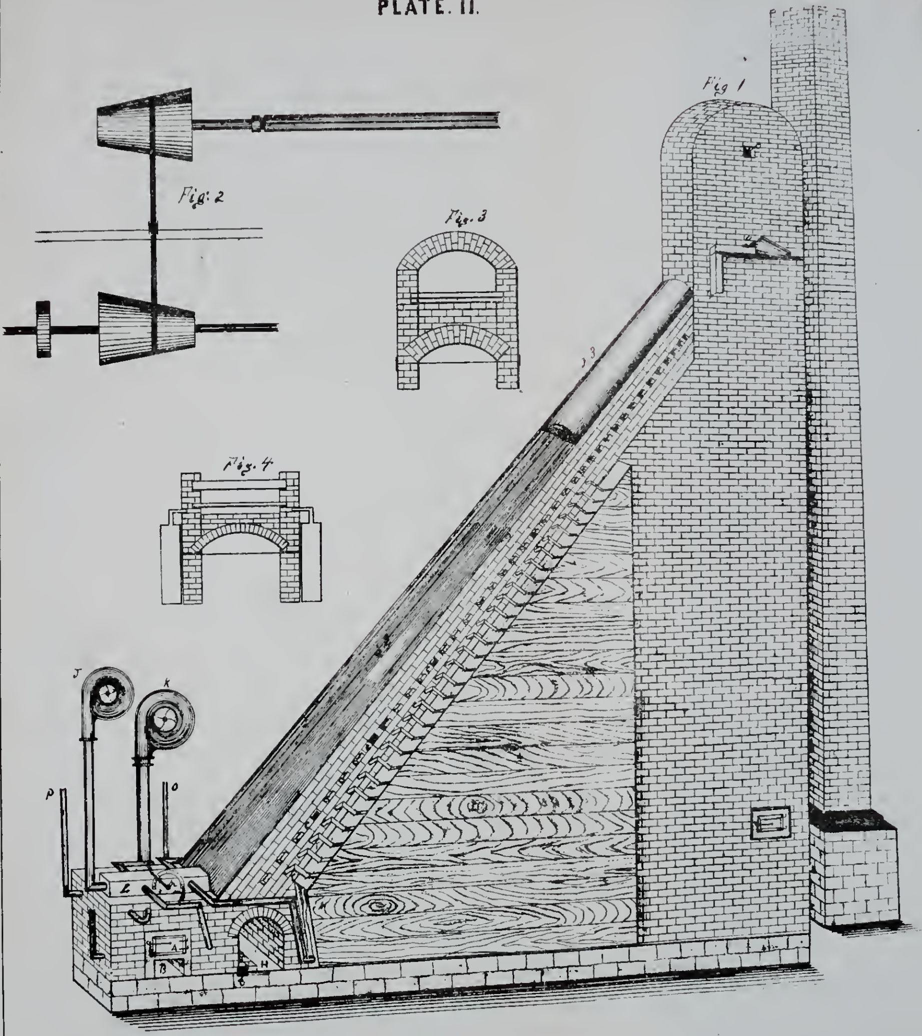
Now, it will be admitted, that a million or an infinite number of particles can be desulphurized in the same time required for the one, could they all be placed in equally as favorable a condition and acted upon simultaneously; and this is one of the objects sought in the plan and construction of the Phelps furnace. The current of ore, continually running down the terraced floor of the oxidizing flue, is four feet in width by forty in length, and so thin or shallow that each and every particle is exposed uninterruptedly to the action of the heat, flame and air. Each particle is independent of its neighbor, so far as exposure to oxygen is concerned. Each particle is *assisted* by its neighbor to heat and flame, hence there is mutual assistance as well as individual independence.

Again, the time required to desulphurize a single particle depends greatly upon its size, a little difference in its superfices making a very great difference in the time required. Thus, take a cube of pyrites one millimeter across its faces, and let us suppose that it can be desulphurized in ten seconds. Now take another, two millimeters across (only twice that of the first), and it will take *eight times* as long to do



Chlorodizing and Cooling Apparatus.

PLATE. II.



Dr. Phelps' Oxidizing Furnace,

PHOTO. LITH. FROM TRACINGS BY A. DICKES, 125 SOUTH FOURTH ST

the work, for the simple reason that its cubic contents are eight times that of the first. So, one three millimeters square will require twenty-seven times as much time for the same reason, and so on *ad infinitum.* Hence, the advantage of pulverizing the ore very finely preparatory to roasting, for if a sieve is used having twenty meshes to the linear inch the time required will be eight times as long as it would be if one having forty meshes had been used. Hence, all other conditions being equal, the furnace that will handle the finest ore, without permitting any considerable portion of it to escape (and the fine gold and silver with it) by force of its draught current, will do the best work and the most of it. This has been one of the great difficulties hitherto experienced, a difficulty entirely obviated by the Phelps furnace, in which the ore is introduced *underneath* the draught current, and passes down the terraced floor of the inclined flue, in a substratum of atmospheric eddies, without being once brought in contact with the ascending current.

In order to understand the construction and *modus operandi* of this furnace reference is had to the accompanying diagrams.

Plate 1.—Fig. 1 is a vertical, central, longitudinal section, showing the arrangement of the terraces, interterrace air slots, subterrace air chambers, &c., &c. A is the fire box, B the ash pit, C oxidizing flue, 4 feet in width, 40 feet in length, and inclined about 50 degrees; E dust chamber, F throat (with damper) leading into chimney, G; H arch, near fire box, containing hot ore pipe, t; I hollow bridge wall; J sheet iron air box with damper; J2 flat roof of fire clay tiles; J3 arched roof; K hopper; L feed roller; m m m terraces of fire clay; n n iterterrace air slots; o o o subterrace air chambers; R feed slot; S discharge; t hot ore pipe.

Fig. 2. Transverse section of hopper and feed roller. Fig. 3. Bisected longitudinal section of same. Fig. 4. Enlarged view of terraces. Fig. 5. Under side of roof over fire box, showing course of hot water pipe for amalgamor, &c. Fig. 6. Ground plan of the furnace.

Plate 2.—Fig. 1. An exterior perspective view of furnace. E atmospheric reservoirs (one on each side of the furnace) receiving air from oxidizing fan, J; F oxidizing pipes, conveying air into subterrace air chambers through perforations in the walls. Each pipe is furnished with a slide valve or damper, and, the quantity of air blown into the reservoirs is regulated by damper m, in air box L; K motor fan, connecting with hot ore pipe, t.

Fig. 2. Feed roller with reversed cone pulleys and belt shifter.
Figs. 3 and 4. Transverse sections of furnace.

Plate 3. t, a continuation of hot ore pipe, into which the ore falls on leaving the furnace, and through which it is blown by the motor fan into cooling chamber B; C ventilators; D sheet iron linging in cooling chamber; E trough of running water into which the ore falls; F vibrating table amalgamator, with contracting arrangement, G; H trough with side pipes, conveying tailings into boxes furnished with syphons, I, and floats for additional concentration.

Modus Operandi.—A gentle current of air passes out from beneath the foot of each step or terrace, from the reservoirs, entering the flue in a *deseendiny* direction, and, coming in contact with the *ascending* or draught current, creates a series of atmospheric eddies immediately over the terraces and in the path of the ore. This arrangement supplies a vast quantity of air, in addition to that coming from the fire box, without carrying the fine gold out of the furnace by force of the draught current. The ore is pulverized dry, and passed through a sieve having forty meshes to the linear inch; then conveyed by strap-and bucket elevators to the hopper, from which it is discharged into the flue *underneath* the draught current. As it falls from terrace to terrace it receives a fresh supply of oxygen from the incoming currents of air; is burned "in suspension" thirty times over, in a constantly increasing temperature, and on leaving the furnace falls into another powerful current of air and is blown through a long zigzag pipe, and is thus repulverized while hot and burning, preparatory to amalgamation.

This is, doubtless, the most perfect arrangement for desulphurizing ore in existence, but the process contains another feature, as valuable as it is novel. Allusion is here made to the "chloridizing attachment" shown in plate 3. The salt mill, A, is connected by a narrow tube with the hot ore pipe, between the motor fan and the discharge from the furnace, A′, by means of which a continuous stream of sodium chloride is blown forward to commingle with the red hot ore, and the disengaged chlorine cannot make its escape prematurely, but is confined within the pipe until it reaches the cooling chamber.

Thus the metallurgist has the choice of two methods, in making use of which he will be governed by the character of the ore, and the best net results.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, ON THE RELATIVE EFFICIENCY OF KEROSENE BURNERS.

By C. J. H. Woodbury.

The laws of the State of Massachusetts declare that illuminating gas, when burning in an Argand jet at the rate of five feet per hour, shall furnish light of intensity equal to twelve times that given by one sperm candle, consuming one hundred and twenty grains an hour.

Therefore, it has been for the interests of both manufacturer and consumer to introduce burners which will give the greatest light with the least expenditure of gas. Much skill and ingenuity has been devoted to the attainment of this result. MM. Audoin and Berad investigated this subject very thoroughly, and came to the decision that there is a design of burner adapted to every rate of consumption.

These researches have been very valuable to all using this source of artificial light; but this is restricted to those living near the centre of population in cities; the greater part of our population, residing in suburban towns, unable to procure gas, are obliged to use kerosene.

The comparative worthlessness of the lighter products of petroleum tempt the unprincipled manufacturer to add them to kerosene, making a product which, on account of its extreme volatility, is *cleaner* than pure kerosene; the flame is of greater brilliancy, and, on these grounds, it recommends itself over the pure oil to those who have not been able to give attention to this subject. Many of these compounds are quite as dangerous as gunpowder.

As kerosene has been in use only a few years, a sufficient interval has not elapsed to enable us to burn it with the greatest possible economy.

The laws for the protection of persons using kerosene must be directly antithetical to those concerning illuminating gas, because the deterioration of the first, causes it to better serve the purposes of illumination at the expense of safety to those using it. This protection is afforded by the declaration that the vapor of the oil shall not be inflammable below a certain temperature.

The writer, in the following series of experiments upon various kerosene burners, has endeavored to ascertain the most favorable forms of burner for an economical expenditure of oil compared to the light given. The results given for each lamp are the mean of from one hundred and fifty to two hundred and fifty observations.

Flat Wicks.

No.	Manufacturer.	Name.	Chimney.	Wick.	Candle Power.	Hours required to consume 1 gallon.	Candle power to gallon.
1	Scovill Manuf. Company............	Standard.	Bulge	⅝″	8·469	99·06	594
2	" ' "	XL.	"	"	6·426	127·53	815
3	Perkins and House...........	Hinge.	"	"	6·587	125·35	823
4	Scovill Manuf. Company...	Imperial.	Sun	"	5·138	163·93	829
5	Collins........................	Sun.	"	"	4·849	171·89	830
6	Scovill Manuf Company............	Imperial.	"	½″	4·810	174·87	835
7	" " " ·...	Hinge.	Bulge	⅝″	7·398	115·23	887
8	Holmes, Booth and Hayden......	Sun.	Sun	"	7·371	131·19	964
9	Scovill Manuf. Company............	Phœnix.	"	"	5·997	188·57	1110
10	Jones, McDuffee and Stratton...	Calcium.	Bulge	1″	10·754	113·17	1209
11	Downer Company	Dual.	"	⅞″	19·48	As these lamps were made to burn mineral sperm oil, we do not give the results.	
12	" "	Dual.	"	½″	10·03		

Circular Wicks.

13	Holmes, Booth and Hayden......	Argand.	Cylindrical.		8·387	101·29	833
14	Jones, McDuffee and Stratton...	"	"		8.824	103·68	911
15	W. H. Batchelder...	Defiance.	"		10·905	123·68	1347

The list could have been made much longer, but it would serve our purpose no better.

The oil used was Downer's kerosene; sp. gr. 0·801. One gallon, at 62° F., weighing 3025·3 grammes. The first column of results shows the candle power given by the lamp when burning with a full flame, but below the smoking point.

The second gives the number of hours required to consume one gallon of oil.

The object of the third column is to give the economy of the lamp, by a unit, which is the candle power given by an ideal lamp, exactly similar to the one under observation, with the exception that it shall consume precisely one gallon of oil an hour.

This result is constant for all except extremely high or low flames.

Such a unit is very empirical, but no more so than the modulus of elasticity, or absolute zero.

If we merely show the phenomena of some lamps differing from others, without the probable circumstances tending to produce such differences, we should not have accomplished our object.

A simple inspection of the above lamps shows their economical results to be in the direct ratio to the facilities afforded the air for approaching the base of the flame. Where the air cannot enter freely, much of the oil seems to be volatilized without combustion.

The best example is given by cases 5, 8, 9 and 10. The lamps are all similar, except in the difference noted below, and are of the pattern generally known as "sun burners."

In the first example, the air must pass through two horizontal brass diaphragms at the base of the chimney; one is pierced with holes $\frac{3}{8}''$ diameter, the other about $\frac{1}{16}''$. Case 8, one fine diaphragm at base of chimney. Cases 9 and 10, the base of the chimney is open; a diaphragm is near the base of flame.

Although the two lamps are different in size, they are identical in principle, the following being the cause of difference in the result:

A certain portion of the light is shaded by the top of the burner. This conceals an equal amount (not proportion) of the flame, whether it is high or low. Also, a large flame makes a much more powerful draught than a smaller one. If we have two similar lamps, the larger one will give the best results.

In the four lamps just cited, if we remove the coarse diaphragm from the first lamp, we increase its efficiency 16 per cent.; in addition, taking away the fine one, we increase it 18 per cent. more; make the draught more powerful by a bulge chimney, and we have a further increase of 12 per cent. Lamps like 9 and 10, from their open construction, are extremely sensitive to currents of air.

The Perkins and House lamp (No. 3) is a metallic lamp, and very thoroughly constructed. The air is supplied from the base of the lamp, the burner being closed; it is not sensitive to currents of air, and gives the most steady and agreeable flame of any that have come under observation. If the entrance to the air passage was made larger, and the diaphragms in the burner were pierced with larger holes, the efficiency of the burner would be increased greatly, while it would probably retain its steadiness of flame.

In lamp No. 15 the air is introduced into the centre of the flame with less obstruction than in the two previous cases, and this lamp gave the most economical results.

LIGHTNING AND LIGHTNING-RODS.

By John M. Mott.

Read before the Meteorological Section of the Franklin Institute.

Lightning is atmospheric electricity moving through bad conducting matter under an explosive form.

A lightning-rod is a conductor of electricity so applied to an object as to prevent the accumulation of free electricity upon it, by induction, and also to enable it to transmit, in safety, the electric force by which it may be assailed.

The prevailing disposition of the times is to apply the discoveries of natural science to useful purposes, and to embody them in those material forms which make them subservient to the wants of man.

Theoretically, indeed, the study of electric phenomena awakens a lively interest in every mind, both on account of the wonderful developments which are constantly made and the subtle and mysterious nature of the unknown agency; seeming, as it does, to occupy the interval between mind and matter.

The construction and application of lightning rods has appeared to most persons a matter too simple to need aid from scientific minds, while not a few have looked upon the whole theory as absurd, and as a source of danger rather than of safety. There has been, consequently, but little encouragement for presenting to the public those facts which are requisite for guidance in applying the discovery of Franklin, successfully, to the protection of life and property.

The fact of electrical conduction by metallic substances having been long and well established, any further discussion of the application of this principle to the purpose of protection against injury by lightning may possibly appear, to persons conversant with such subjects, in some degree superfluous. The damage, however, which so frequently occurs in thunder-storms, attended, as it is, with loss of life and with serious inconveniences to the best interest of the country; the various theories advanced by persons who have only partially considered the facts; systems of rodding which have been adopted in different localities, and the numerous modifications of the conductors, each claiming some peculiar advantage over all its competitors, has created a curiosity, if not a necessity, which seems to call for investigation and may be fairly offered as a sufficient reply to such an opinion.

Many lives and a vast amount of property are constantly and needlessly jeopardized.

How the great risk is incurred and safety attainable I will endeavor to demonstrate.

The years 1745 and 1746 mark an important era in the history of physical science.

Von Kleist, Dean of the Cathedral of Kamin, and some Dutch philosophers in the University of Leyden, in endeavoring to confine electricity within the limits of a small phial, discovered a method of accumulating it on glass to a most unprecedented degree, and of subsequently discharging it through bodies in such a way as to produce most powerful and astonishing effects.

By these discharges, a fearful sensation could be impressed upon living animals, even life itself destroyed; metallic substances could be violently heated, fused and ignited; inflammable bodies set on fire, and the most compact substances scattered in pieces, as if acted on by a violent expansive force. When, therefore, lightning became identified with ordinary electricity, with the very element, as it were. by which such effects were produced, and the wonderful attempt of Franklin, about seven years afterwards, to *conduct* electricity from the clouds, and appropriate it in a similar way to the purpose of experiment, had fully succeeded, then it was that those artificial accumulations and discharges acquired a more than ordinary interest, as furnishing us with a valuable means of investigating, by minor experiments, the laws and operations of the great discharges in thunderstorms.

When we consider the coincidences of lightning and ordinary electricity, together with the fact that atmospheric electricity may be conducted from the clouds, or strata of charged air, and applied to produce the same effects as those resulting from electricity generated by means of an electric-machine, it becomes quite evident that the causes, whatever they may be, of ordinary electricity are identical with those of lightning; consequently we arrive at the important conclusion that lightning and common electricity are subject to the same laws— a deduction which cannot be too forcibly insisted on, involving as it does the most valuable practical consequences.

The accumulation of electricity by artifical means may be carried to an almost indefinite extent, and is equally manageable whatever may be the extreme limit of force we choose to assign to such accumulation. It therefore necessarily follows that discharges of atmospheric electricity may be quite as easily directed by a judicious and scientific arrangement of conducting bodies; such discharges being, in fact, nothing more than discharges of the same force accumulated in a similar way by means of an apparatus of a perfectly similar kind.

The vapory masses of electrified clouds opposed to the surface of land or sea oppositely electrified, by induction, with the non-conducting medium, air, intervening, constitute a battery of enormous power.

The circumstance of the coatings of the Leyden jar being metallic, while those of nature consist of clouds and opposed land or sea, is a difference of no consequence whatever, especially when we consider that the original Leyden jar of the Dutch philosophers consisted of a phial filled with water, from which they obtained so severe a shock that one of them said he would not again receive it for the whole kingdom of France.

It is conceded that the atmosphere contains free, or uncombined, electricity; that clouds as they pass through the air collect and retain it in large quantities, thus becoming electrified bodies; that they are sometimes positively, sometimes negatively charged; that it is impossible to have a body charged with one kind of electricity without having an equal amount of the opposite kind accumulated in near or distant bodies; that the attraction between the opposite electricities is mutual, and that it increases as the distance diminishes.

It is well known that an electrified cloud acts upon the earth by induction; decomposes the combined electricity in every object over which it passes; repels the electricity of the same kind as that contained by itself, and attracts the opposite kind. The earth and objects beneath an electrified cloud are in this manner charged by induction. When the attraction between the opposite kinds of electricity becomes greater than the resistance of the intervening air a discharge takes place. It is this accumulation of free electricity upon buildings, by induction, which offers the attraction for the opposite electricity contained in the electrified cloud, or stratum of atmosphere, that causes them to be struck by lightning. The accumulation of free electricity in large quantities is the necessary condition, and the effects follow as a natural consequence. Thus his Majesty's ship Dictator was struck and damaged by lightning at Martinique, in the year 1794, during fine weather and a clear sky.

If a discharge takes place, from any cause whatever, at any point, the cloud is left in a neutral condition, induction instantly ceases, and all the bodies charged by induction instantly return to a neutral state.

The suddenness of this return is what is known as the return stroke, and often kills men and animals, or destroys buildings which are at the time at a great distance from the place where the direct discharge occurs. All the terrible effects of the return stroke may result when the direct discharge has been between two oppositely electrified clouds.

Nothing attracts electricity except electricity of an opposite kind. All substances conduct it in a greater or lesser degree. Metals offer less resistance to its passage than other substances.

If a disruptive discharge takes place between oppositely electrified bodies, it will pass through the line or lines which, upon the whole, offer the least resistance to the neutralization of the electric forces.

Both time and space are, as it were, economized; for, however small we assume the duration of the discharge to be, or however limited the distance through which it strikes, both these, time and space, would be still less were other lines of discharge provided of still less resistance. This is the leading phenomenon of all disruptive discharges; hence lightning seizes upon such bodies as lie convenient and ready for its transmission, actually avoiding other bodies, however near, from which it cannot receive assistance.

It is a most wonderful and interesting truth, demonstrable by the laws of induction, that, at the instant before the discharge takes place, the electricity, in the act of moving to restore the equilibrium, feels its way, as it were, in advance, and absolutely marks out the course it is about to take, by the polarization of such bodies as form the line of least resistance. This previous polarization of the line of best conduction determines the course of the discharge. Its progress, therefore, is not, as many suppose, left to the chance of the instant, to be drawn aside by metallic bodies at any given point. On the contrary, the whole course of a thunderbolt is fixed and determined before the discharge occurs.

The evidence deducible from observation, as well as from physical investigation, is most conclusive on this point.

In the accompanying cut, C represents an electrified cloud; E, the earth; N P, a

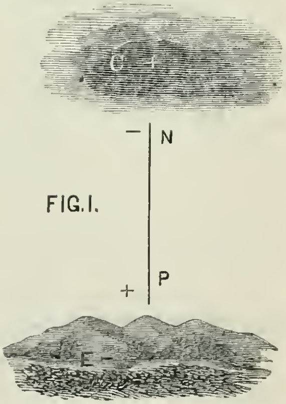


FIG. I.

good conductor, suspended between the cloud and the earth. If the cloud be charged with positive electricity, the rod will be polarized as indicated; that is, the upper end of the rod will be negatively charged, and the lower end positively charged, and the earth will be negatively charged. If we assume the cloud to be charged negatively, the polarity of the rod would be reversed, and the earth would, in that case, become charged positively.

The cloud, situated as shown in the diagram, might be so far removed from the earth that the mutual attraction between the positive electricity contained by the cloud and the negative electricity contained by the earth could not overcome the resistance of the air, consequently there could be no discharge.

If we suppose the cloud to be moving through the air, we can readily see that the earth now immediately beneath the cloud would gradually return to its normal condition. The effect of placing the conductor, N P, between the cloud and the earth, as shown in the cut, would be to lessen the resistance between them, by offering a better line of conduction than that offered by the intervening air. If a discharge should occur while the rod is in the position indicated, it would become part of the line of discharge determined, by polarization, before the discharge took place, and not by attraction after the electricity had started to restore the equilibrium.

If the rod be disconnected from the earth, any conducting body between it and the earth would also become part of the line of discharge, while insulating matter would be attacked with destructive violence.

This diagram is intended to illustrate the contempt architects and builders display of electrical laws in the erection of high spires, which are frequently terminated with a metallic shaft attached to a cross timber within the tower, and supporting a gilded ball or ornamental vane. They also have metal clamps and strings of lead, the former uniformly placed at intervals from each other, and the latter wantonly poured into the crevices of the masonry, which makes the spire a complete chain of alternate links of metal and masonry from top to bottom, the former offering a safe line of conduction, so far as it goes, and the latter facilities for the most destructive explosions.

It is almost a miracle that the whole of them, instead of a part only, are not destroyed by lightning. It also illustrates the condition of buildings having metallic water conductors or lightning-rods disconnected from the earth (the owners of which know the fact, but, from ignorance or indifference, allow them to remain in an improper and unsafe condition), and that of every building having gas or water pipes which are not connected with lightning-rods extending to the top of the structure and terminating in points.

We have stated that the rod N P would facilitate a discharge between the cloud and the earth. It is immaterial how that rod is supported, or for what purpose it may be used, as it offers a line of less resistance to the restoration of the electric equilibrium than the materials from which buildings are constructed, and is, therefore, likely to become a part of the line of discharge, in case of a direct or return stroke. In case damage ensues to a building from lightning, it will not be where good metallic conductors are continued.

In the following cut, Fig. 2, we have C, the charged cloud, and, beneath it, B, a building.

In this case we represent the cloud as being negatively charged; the building will be positively charged by induction, as indicated; A is a chimney, with smoke escaping from it into the air. In case a discharge should occur while the cloud is immediately above the building, the smoke above the chimney, the inside of the chimney, the stove-pipe and stove would be most likely to be the line of least resistance, and consequently would become part of the line of discharge, should an explosion ensue.

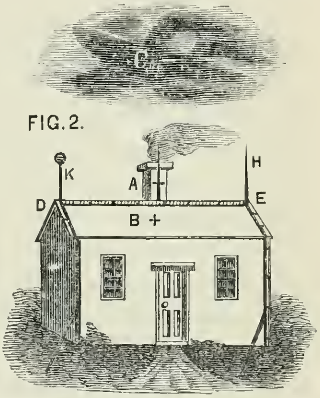


FIG. 2.

If the cloud be approaching the building from the left, the cone of the roof at D would be the nearest geometrical point; it would also be the most highly charged point of the building, as the free electricity of the building would be attracted by the opposite electricity contained in the approaching cloud, and would tend to accumulate upon that portion of the building, in accordance with well known laws governing the accumulation of free electricity upon bodies when differently situated with respect to oppositely electrified bodies; it would offer greater attraction than any other portion of the building; hence it would be most likely to be struck in case a discharge should ensue while the cloud is approaching the building from the left. We have already stated that it is not the materials of which the building is composed that offer the attraction, but the free electricity held on it by the attraction of the opposite force contained by the approaching cloud. The nearer the cloud approaches the building the greater becomes the accumulation of free electricity upon it, and as the distance diminishes the attraction increases.

If, while the cloud is at the left of the building, a rod, K, terminated, as shown, in a ball, be placed in contact with the building at D, it will conduct the free electricity from the building to the ball, which will show its electrical condition if an electrometer be attached to it. It is evident that the ball and rod will become part of the line of discharge as soon as the electrical attraction is sufficient to overcome the resistance. Any means which will prevent the accumulation of electricity by induction at the point D, will prevent the building from being struck at that point.

There is one law of electrical action which some electricians lose sight of entirely in considering the subject under immediate investigation, viz., that large quantities of electricity pressing upon small surfaces become quite unruly, and when the surface is reduced to a mere point the tension becomes so great as to give rise to an escaping current. If, instead of terminating the rod K in a ball, we use a finely plated point, as shown on the rod H, attached to the building at E, we will at once have a flow of free electricity from the building into the air by means of the rod and point, and as the particles of air become charged they will be repelled by the electricity being conducted from the earth by the rod, and attracted by that contained in the cloud. The escape of electricity from the points of the electric wheel, and the effect produced upon a charged conductor, when slowly approached with a metallic point, held in the hand, are demonstrations of the fact that electricity escapes from points, and neutralizes charged bodies with which they are not in contact. Thus it will be seen that a pointed conductor, placed directly in contact with a building, tends to prevent the accumulation of electricity upon it, and also to neutralize the charged cloud; hence it may prevent a disruptive discharge which might otherwise occur. If the rod be removed from the building by insulation, it is powerless to prevent the accumulation of electricity on the building by induction; hence by insulating a rod we lose its most valuable influence. If the rod be insulated while it has a tendency to neutralize the cloud by conducting and discharging the opposite kind of electricity from the earth, it may also facilitate a discharge, for the reason fully explained in connection with Fig. 1. If a discharge falls upon an insulated rod, and be conducted by it to the earth in safety, and without intermediate explosion, still the conditions requisite for a return stroke are present, and the insulated rod is powerless to prevent injury to the building or its contents at the *very instant* of the direct stroke.

Phenomena of this character are quite frequent, especially where buildings have gas or water pipes to lead the return stroke into the house, and in consequence many have condemned the use of lightning-rods without investigating the cause of the disasters.

The closer rods are applied to the walls of a building the better: indeed, it is absolutely necessary to attach the rod directly to the object to be protected, to insure safety, for no other way can we guard against the return stroke, which kills more people and destroys more property than the direct stroke.

The rod must not be placed at a distance from the object to be protected, nor pass over nor through rings of glass or other insulators. Insulators are not only useless but are positively dangerous before rain falls; after rain falls they acquire some degree of conducting power; at best, they are entirely useless as a means of safety, make an insecure fastening and allow the rod to rattle sufficiently to disturb sick or nervous people at all seasons of the year. Their use should be discontinued, and some method taken to induce parties, having rods upon their buildings which are insulated, to remove the glass.

It is a physical impossibility for any object to be injured by lightning if the conditions of safety, known to be demanded, are fully complied with.

I have no doubt but the case mentioned in Sillman's Physics, page 662, second edition, illustrates the result of insulation. It is stated: "In a church in New Haven the lightning has twice penetrated a 20-inch brick wall at a point opposite a gas pipe 20 feet above the earth, although the conductor of $\frac{3}{4}$-inch iron was well mounted, but its connection with the earth was less perfect than that of the gas pipe." I suppose "well mounted" to mean well insulated. Now, suppose lightning to fall upon this well insulated rod and be conducted by it to the earth in safety, or a discharge to take place between two clouds. In either case the building would at the same instant return to its normal condition, and the gas pipe would be part of the line over which the electricity would pass to restore the equilibrium. The effect produced by lightning on this church upon two different occasions are such as might have been anticipated, and are likely to occur again, unless the rod be attached directly to the building, *and also to the gas pipe* near its upper terminus. It will make but little if any difference at what point the rod and gas pipe are united; if the connection be made about the building it will be less liable to get out of order than it would be if made in the earth. It is contrary to all known laws of electrical action to suppose that electricity, passing over a rod which penetrates the earth, would leave such conductor before reaching its termination, unless some other equally as good a conductor is in contact with it and also extending to the earth, in which case the charge would be carried in part by each without injury to surrounding bodies, providing one of the conductors be a ¾-inch iron rod.

The distribution of free electricity over the surface of electrified bodies, depends upon their form and the position which they occupy with respect to surrounding bodies.

It is conceded that the greater the curvature of a surface at any part, that is, the nearer it approaches a point, the greater will be the accumulation of electricity there; that electricity tends to flow towards, or accumulate at, the pointed portions of bodies; that metallic bodies of a pointed shape soon lose the electricity imparted to them, and that it is impossible to charge a conductor when a sharp point projects from it, or one having conducting communication with the earth is held near it. Points are of value aside from preventing the accumulation of electricity on the object to be protected and their tendency to lessen the intensity of the cloud. Having become the origin of an active mechanical force, do, by the very act of causing that force, namely, by discharge prevent any other portion of the conducting body from which they project from acquiring the same conditions, and thus preserve their own predominance.

A geometrical point is without dimension. A practical point has dimensions which are, in comparison to some other body, quite insignificant. Some electricians, still accepting the absurd one-fluid theory of Franklin as being true, claim that points draw off electricity silently and quietly from charged bodies with which they are not in contact; that a cross section of any lightning rod would be an infinitely small point in comparison to a cloud, and therefore the points upon lightning rods are useless except as ornaments.

The cross section of a lightning rod would be, as claimed, an infinitely small point in comparison to the area of a cloud; but, unfortunately for the advocates of the one fluid theory, points do not receive electricity from charged bodies with which they are not in contact, except in cases of disruptive charge.

The silent flow is always from points, never towards them. Electricity cannot leave the cloud except by conduction or disruptive discharge. The upper termination of a lightning rod must be a mere point in comparison to a cross section of the rod upon which it is used. The object in terminating the rod in a point is to increase the electrical tension at its upper extremity sufficiently to give rise to an escaping current of electricity from the rod. If the upper portion of a lightning rod be insulated and separated from the lower section by a slight opening, electric sparks will pass through the space during the passage of electrified clouds so rapidly that neither the eye nor the ear can discover the intermissions. If the point be removed the sparks will cease. This experiment demonstrates the value of points and proves that lightning rods do tend, as before stated, to neutralize charged clouds. If the upper end of rod, N P, Fig. 1, be terminated in a ball, or be inserted into the mouth of a glass bottle, a disruptive discharge would be through the conductor, as it would still be the line of least resistance. At the instant of discharge, it is a matter of but very little consequence whether the rod be terminated in a finely plated point or within a pop bottle. Polarization will take place nearly as well through glass as through dry air. I have not the slightest doubt but buildings would be destroyed by lightning, either by the direct or return stroke, were they encased with glass coverings one half mile thick. Points are of vital importance before the instant of discharge arrives.

(To be continued.)

Removing Phosphorus from Iron.—Some improvements in effecting the removal of phosphorus from pig-iron during the puddling process, have been introduced by Prof. Scheerer, of the Mining Academy of Freiberg, in Saxony. Chloride of sodium and chloride of calcium are mixed in about equal proportions, and the two salts are fused together. The fused mixture is run into water-proof paper cases, each holding about two pounds, and these cases are introduced into the furnace one by one, so that the dephosphorizing mixture may be thoroughly incorporated with the charge. To insure satisfactory results, it is recommended to use three times as much of the mixture as the iron contains phosphorus.

DECAY AND PRESERVATION OF TIMBER.

(Continued from page 53, Vol. LXVI.)

Measure of Economy in using Creosoted Railroad Ties in the United States.—As a general rule in this country, ties untreated last about seven years before they require renewal. We have a right to suppose the treated ties endure as long as the average in foreign countries, which I find is twenty-eight years, and then perfectly sound; but to be on the safe side of our estimate of economy, suppose the treated ones should give out at the expiration of twenty-eight years and then require renewal. Constructing the road at first with untreated ties; after that, there would be four renewals with the untreated in this period; but as the last renewal would belong to the next epoch, we have to set the cost of four constructions (*i. e.*, the first construction and three renewals) with the untreated against the cost of one construction with the treated ties.

All railroad companies pay interest on funds for construction at a rate of not less than six per cent. per annum. This interest item should enter into the estimate.

On the different roads traversing our country the price of ties, the cost of the labor in laying them, and the cost of treatment vary, though not very materially. We will suppose these prices to vary, however, and let

T be the average cost *in cents* per untreated tie on any road, delivered where the tie is laid in the track.

L the cost per tie *in cents* of the labor of laying the tie in the track where it will require renewal every seven years.

ϕ the cost *in cents* of treating the ties before laying, at some convenient place for the location of the apparatus for treatment.

And by taking the interest only at six per cent. on the outlays, the interest paid only annually instead of semi-annually, and compounding it, for the four outlays, seriatim, from the time each is incurred to the expiration of the epoch of twenty-eight years, I make the following formulas:

$$\left.\begin{array}{l}
\left.\begin{array}{r}\text{Cost in cents per tie untreated,}\\ \text{for twenty-eight years,}\end{array}\right\} = 12.276 \times (T + L)\\
\left.\begin{array}{r}\text{Cost in cents per tie treated,}\\ \text{for twenty-eight years,}\end{array}\right\} = 5.112 \times (T + L + \phi)\\
\left.\begin{array}{r}\text{Saving in cents per tie by}\\ \text{treatment, in 28 years,}\end{array}\right\} = 7.164 \times (T + L — 5.112 \times \phi)
\end{array}\right\} \quad (1)$$

APPARATUS USED IN CREOSOTING TIMBER AT ST. CLAIR FLATS, MICH.

PATENTS OF SEELY & PELTON.

Accompanying Report of Genl. T. J. CRAM, U.S. Corps of Engineers, to the Chief of Engineers, U.S.A.

1871

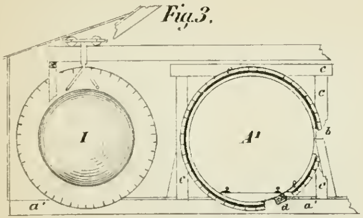


Fig. 3.

Scale
8 ft. = 1 inch.
12 6 0 1 2 3 4 5 6 7 8 9 10 feet

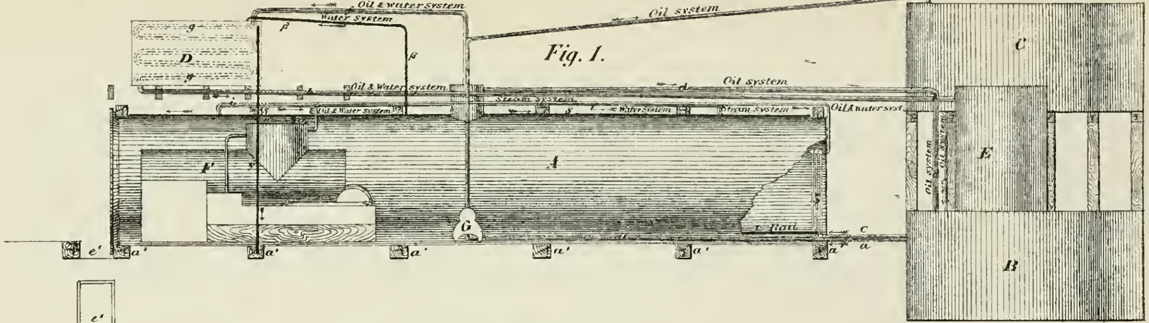


Fig. 1.

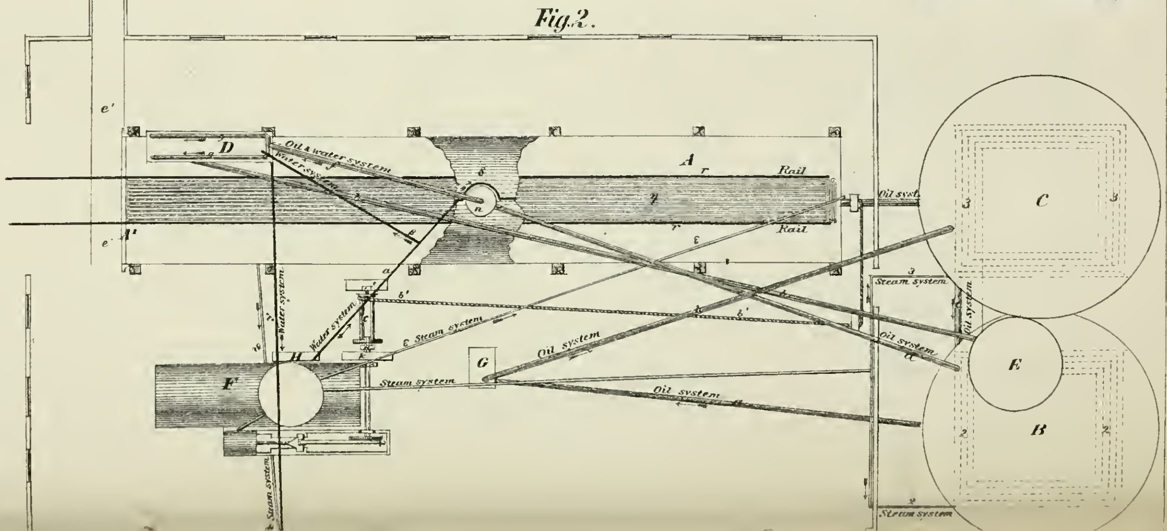


Fig. 2.

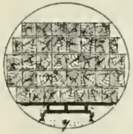


Fig. 4.

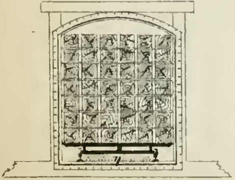


Fig. 6.

Fig. 5.

Eng. in the Engineers Bureau.

These formulas (1) being applicable to any road. Suppose, for example, we apply them to one upon which T=42 cents, L=25 cents, and ¢=35 cents. Substituting these in (1), we shall find

Cost per tie untreated, for 28 years=$8.22.

Cost per tie treated, for 28 years=$5.21.

Saving per tie by treatment, for 28 years=$3.01.

The saving would be 10.715 cents per tie, annually, which would be 25½ per cent. of first cost of the untreated tie.

On a mile of road, there would probably be 2,376 ties, for heavy work on the track. The saving per tie (10.715 cents) applied to this number, would make the saving to the company, by treating the ties in the first laying of them, amount to $254.58 per mile per annum.

But there is a limit to the cost of treatment beyond which there would be no saving to the company. Let ¢′ represent the limiting cost in cents per tie for the treatment, and we shall have in any road,

¢′=1.4×(T+L) . . . (2), from which, by substituting the values of T & L, we shall find ¢′.

In the foregoing example, where T=42 cents, and L=25 cents, we shall find ¢′=94 cents, nearly.

We may say as a general rule applicable to all railroad tracks that a treatment which would make the ties last only for twenty-eight years, and should cost one and four-tenths (1.4) of the sum of the cost of the untreated tie and of the laying of the tie, there would be no advantage in the treatment as long as money could be had at six per cent.

In the United States, the price of ties has been progressing since wood was first used instead of stone bearers, A. D. 1862. In 1838, I remember, fourteen cents per tie was a full price per tie for oak and chestnut of the best quality, in Maryland. The price will hereafter keep advancing until some process of treatment shall enable us to use an inferior quality of timber for them. Wood that will hold the spikes the best and last the longest, is the desirable kind.

III. *Processes of Treatment.*—It certainly seems that the mode of treatment which shall insure the most perfectly, the following conditions would be the most effectual in preserving the wood:

1st. To displace or destroy the albumen and the natural acids in the wood, and empty its pores of all corroding or fermenting substances.

2. To infuse into the pores thus emptied a powerful antiseptic, which in itself will not weaken the fibre, and at the same time be in-

soluble by water, and of a tenacity to resist being soaked or washed out, and thus preventing admission into the pores of all extraneous matter.

3d. To be exempt from deleterious effects upon the health of the men employed in conducting the process, and of those who handle the treated wood for the construction.

It is obvious that, whatever process be used, the greatest care should be taken to guard against injury to the fibre. Injury has arisen and will again arise in the multitude of processes starting up all over the land, from the corrosive nature of the quack antiseptics; also from too much heat in the application. Kyan's process, dating back to the year 1832, although he claimed that timber treated with it resisted rotting substances in vats for 23 years, and was then as sound as ever, signally failed to answer conditions 2 and 3. It utterly failed to resist the sea worm, and produced such sickness in the employes as to condemn its use.

From the results, however, of the experiments quoted in Tables A, B, C, Chapter II, it will be acknowledged that Bethel's process in England, dating back to A. D. 1838, answers to the three conditions I have named, better than any practiced from the time of Kyan's to that of Seely's in the United States in 1867.

Bethel's was named "creosoting," and still bears that appellation, though a misnomer. From the first, his method has consisted in using what was called "creosote oil" in England, "pitch oil" in Scotland, and "dead oil" in the United States, and which is either distilled from that substance (coal tar) left in gas factories after the illuminating gas comes off from bituminous coal, or directly distilled from the coal itself. It is considered to be heavier than water at the same temperature.

Bethel applied this oil by putting it with the wood into and nearly filling a strong iron receiver, then closing the receiver, and forcing more oil into the receiver until the pores of the wood become saturated, requiring a pressure of 13 to 14 atmospheres.

Now, while this mode of application, which I believe is still followed in England and at Rotterdam, would be sufficiently good perhaps, for *well seasoned wood*, any one can see it is illy adapted to *green*, *wet*, *or unseasoned* timber, because the sappy and other fluids inherent in the pores would not be expelled before the admission, indeed, they would virtually prevent the admission of the antiseptic. Remedies have been sought in soaking, steeping, and boiling the wood in the oil; also in steaming, but without much success. The boiling point of the oil is high, 500° to 600° F. This degree of heat, as also previously subjecting the wood to a steam bath, produced bad effects on the fibre.

It is obvious, the process to be of the widest practical benefit, should enable us to treat green, wet or water-logged sticks of timber, 30 to 40 feet long and 10 to 12 inches through, and even larger sticks for piles.

The method of application patented by Professor Charles A. Seely, of New York, in 1867, is a modification of, and an undoubted improvement upon Bethel's process, in being applicable to green, water-logged wood, and with far more efficiency even to seasoned wood, differing materially, however, in the mode of application of the dead oil.

This new process consists of immersing the wood in a closed iron tank of the oil, raising the whole to a temperature between 212° and 300° F. This action is allowed to go on until the moisture or water contained in the wood is expelled, or has escaped in the shape of steam. The water being supposed thus expelled, and the pores containing little or no steam, the hot oil is suddenly replaced by a bath of cold oil, condensing all the remaining steam, and thereby leaving a total or partial vacuum in the wood cells, into which the oil immediately rushes, impelled by the hydrostatic pressure of the oil, the pressure of the atmosphere, favored also by capillary attraction.

Those who favor this process claim for it the following results:

1st. The effect of the hot bath is to sufficiently season the wood, and destroy or coagulate all the albumen and expel the water and other fluids from the pores.

2d. The effect of the cold bath is to impregnate the wood cells with the antiseptic (carbolic acid), and at the same time stuff, as it were, the pores that will for a long time after exposing the timber to the air, variations of atmospheric temperature, soil, rain, salt or fresh water, resist absorption of destructive agents in all these sources, the borers in salt water, worms on land, and white ants in tropical climates inclusive; and also prevent the rusting of iron bolts, spikes, nails, etc., in treated wood.

The stuffing substance with which the pores are filled, is supposed to be tenacious and insoluble in fresh or salt water. It is called "hydro-carbon," or "resiniform." I am inclined to believe this is the substance, from the fact that in the arts, if the dead oil is carried through another stage of distillation, a very useful varnish is obtained, having great preservative qualities for heavy linings under the sheet-ing boards of houses. But this is an unnecessary digression; nor do I intend to give a chemical analysis of this substance.

The lapse of time and then careful observation are the only means of certain tests for the efficacy of this or any other process.

Knowing that Bethel's had effectually preserved seasoned timber 21 to 32 years, which was then reported to be as sound as ever in foreign countries, but believing his method illy adapted to our green, wet timber, and believing Seely's process could be made suitable for this kind of timber, I recommended the adoption of it on the 6th of April, 1868, for the timber *above water* in the U. S. public work, known as "St. Clair Flats Ship Canal, Mich."

The recommendation was appreciated and promptly approved by the chief of the U. S. corps of engineers, Bvt. Major-General and Brigadier-General A. A. Humphreys.

Accordingly I made a contract with W. T. Pelton, of 157 Broadway, New York, who controlled the Patents, to treat the timber, he doing and furnishing everything, except the timber, for fifteen cents per cubic foot, receiving the timber at the hands and convenience of the constructing contractor, and placing it after treatment convenient for the latter to take away, for framing and putting the treated timber into the dykes of the canal.

After getting the apparatus completed, the application of the oil was commenced in May, 1869, and finished 15th June, 1870.

The timber was of superior quality, well-sawed Michigan hard and white pine, (the first called by some red and by others Norway pine.) This kind in Michigan has very little resin in it. The logs for this timber were cut in winter and sawed in the following spring and summer; some were rafted from the mill to the work, some were brought in vessels, and taken green and water-logged immediately and put through the process.

The sticks were in sizes 12″ × 12″, 20′ long; 10″ × 12″, 20′ long; 8″ × 12″, 20′ long; 8″ × 10″, 14′ long.

The total amount treated was, 186,580 c. f.

It would be very difficult to fully understand the method of applying the "dead oil," without a knowledge of the apparatus. I therefore give the explanation and drawings of the apparatus in the next chapter, which I advise every reader of this to carefully notice. This apparatus, I understand, was patented by the said Mr. Pelton, for the particular application of Professor Seely's process.

IV. *Construction and Mode of Working the Apparatus for treating* *of the dike timbers by Seely's process, for the St. Clair Flats Ship Canal.* (*Treatment commenced May* 5, 1868, *terminated June* 15, 1870.—On the accompanying sheet of drawings, Figs. 1 and 2, are vertical and horizontal projections showing the relative positions of the parts of the apparatus.

The timber tank A′ A (Figs. 1 and 2) is a cylindrical vessel made of boiler iron, only three sixteenths of an inch thick, forty-five feet long, with an interior diameter of eight feet. In Figs. 1 and 2, portions of the surface are represented as cut away to show the positions of the steam coils at ξ and η and the rails *r*, *r*, on which the timber cars are drawn.

One end of this tank is closed by boiler iron plates riveted as ordinary boilers, and strengthened by heavy iron braces, not shown in the drawing, while the other end is to be closed or opened by a cast iron cover one inch thick, seen in Fig. 3, at I. This cover is nine feet in diameter, with a radius six inches longer than that of the tank, that it may fit the cast iron rim which is riveted around the head A′ of the tank. A cross section of the rim on a large scale is represented in Fig. 5. At *e*, in the same Fig. 5, is represented a cross section of a groove filled with an india rubber band corresponding.

Part of the surface of the cover is pushed out as it were, and the cavity left is crossed by ribs deep in the centre to give strength. In the periphery of the cover and rim, corresponding slots are left large enough to admit of the easy sliding in and out of $\frac{3}{4}$ inch bolts; by this arrangement the cover is put tightly on or taken off at pleasure. It is needless to remark that when on, the cover must fit "oil-tight."

The firm bed upon which the timber tank rests is made of six pieces of square 12″ 12″ timber laid eight feet apart in compact sand, the cross section of which is shown in Fig. 1, at *a*′, and seen in side elevation in Fig. 3, at *a*′. Across this, parallel to the axis of the tank and directly under the rails *r*, *r*, which are in the tank, are two pieces of 6″ × 8″, shaped on their upper surfaces to lay well against the surface of the tank and let into their bearing (12″ × 12″) pieces, as seen at *c*, *b*, Fig. 3.

To prevent warping or flexure, a frame of 8″ × 8″ timbers on each side of the 12″ × 12″ bed pieces is arranged to support the tank as shown at *c*, Fig. 3, assisted by intermediate studs capped with a wrought iron ear riveted to the tank, as seen at *b*, Fig. 3.

This tank A′ A with the steam engine boiler F, the condensing tank D, and the engine and pumps are covered in from the weather by a slight roof, but the tanks B, E, C, are in the open air.

For convenience I divide the many pipes connecting the various tanks into four systems, as follows :

1st. The "oil system," or those pipes conveying oil, lettered with *italics*.

2d. The "oil and water system," those that convey the vaporated oil and sap from the timber tank to the condensing tank D, and the condensed liquids to the wooden receiver. This system of pipes is also lettered with small *italics*.

3d. The "water system," or those conveying water, lettered with small Greek letters.

4th. The "steam system," those conveying steam, outlined in black, or indicated by broken black lines and lettered in Greek, or indicated by figures.

These systems are so arranged as to allow all the liquids to be drawn from them when necessary, to prevent freezing and bursting.

Let us suppose a bill of timber 12 × 12's, 8 × 12's, and 6 × 12's, twenty feet in length, is on hand for treatment. Two cars are loaded with these timbers (called a "batch") by means of a swinging crane, the pieces arranged as seen in Fig. 4, cross section. The loaded cars are then hauled into the tank by means of a rope b', Fig. 2, rendering through an aperture in the end of the tank, and wound over the drum c'; this aperture is closed with a plug when the rope is detached from the load.

The batch being drawn to its place in the tank, the moveable parts of the track *r*, *r*, Fig. 2, spanning the trench *e*' are removed, the cover drawn over the head of the tank and firmly bolted. In the meantime, the oil tank B, made of boiler iron, and sunk in the ground so its top is thirty inches above the ground surface, has been filled with oil directly from the barrels, and the oil pumped from B, through three inch pipes *a*, *b*, Figs. 1 and 2, into the iron tank C (which is raised entirely above the timber tank and rests on a stand framed with timber), by a rotary pump G, worked by a band from a band wheel *k* on the crank shaft of the engine.

Now the valve in the five inch pipe at *c*, Figs. 1 and 2, is opened, and the oil from C rushes into the timber tank and is allowed to cover the batch to the height of three inches above all the timber, which height is tested by a stop-cock in the end of the timber tank. As soon as this rushing in of oil commences, the valves in the one inch pipe ε are opened and the steam from the boiler F is forced through it with a pressure of about three atmospheres, into the upright steam coil ξ, Fig. 1, in vertical and in horizontal projection ξ, Fig. 2; thence into the horizontal coil seen lying between the rails *r*, *r*, at η, Fig. 2, and in cross section at η, Fig. 4. From this coil the steam finds its way into the open air through pipe δ, Fig. 2.

While the oil in the timber tank A is thus being heated, more oil is emptied from the barrels into B, and pumped thence by G through pipes *a*, *b*, into the upper tank C, ready to be rushed into A.

As soon as the temperature of the oil in the timber tank A is up to somewhat less than 212° F., the sap fluids and air contained in the timber expand in the pores and rise to the top of the oil, the air passing off with some of the oil that is also vaporized, passing into the dome *n*, from the central portion of the tank, and passing from the extremities by pipes *i*, *i*, Fig. 1.

From the dome the vapors are conducted into the condensing tank D, by the 3-inch pipe f, passing through the coils g, g, where they are condensed and carried into the wooden tank E, by the 2-inch pipe *h*, in which tank they separate by virtue of their difference in specific gravity, the water sinking to the bottom is drawn off, and the oil transferred to the tank B, and not wasted.

While this condensation is going on, cold water is continually supplied to take the place of the water warmed by contact with the coils *g*, *g*, by the pipes δ, β, Figs. 1 and 2, from a donkey pump placed at H, Fig. 2, while the warm water passes off from the surface through the pipe ν, Figs. 1 and 2.

When the sap fluids cease to come over, the steam is cut off, a valve in the water pipe β, is closed, and the water is forced through the pipe δ, on the top of the timber tank [δ has small holes pierced in it to allow the water to escape from it in little jets over the surface of the tank], at the same time a valve in pipe *c* is opened, and the cold oil rushes in at the bottom of the timber tank, while the hot oil in this tank, in virtue of its less specific gravity, keeps the surface, and is discharged through what is called the "overflow pipe," marked *d*, in Figs. 1 and 2, into tank B.

As soon as the timber in the tank is sufficiently cooled, the oil in B is pumped into C, and the oil in the timber tank is transferred to B by pipes *c* and *e*; the cover of the timber tank is then removed, the movable rails *r*' *r*' replaced, the cars with their batch drawn out by shifting rope *b*', to a moveable pulley in front of the tank; and another batch, standing already on a side track, is run in to take the place of that just drawn out, and treated in the same manner.

As dead oil congeals readily, tanks B and C are furnished with coils of small steam pipes, shown in Fig. 2, at 2 and 3, fed by a single pipe 1, Fig. 2, from the steam boiler to prevent congelation.

With this description, the drawings will enable one to understand the *modus operandi* of the Seeley process.

(To be continued.)

NICKEL AND ITS USES IN THE ARTS, COINAGE AND NICKEL PLATING.

By Dr. Lewis Feuchtwanger.

The name of nickel was given by the discoverer, Cronstedt, in 1751, in derisive manner, it having been extracted from the ore called copper nickel. The Saxon miners, in search of copper, discovered a mineral resembling copper in appearance and color, but were disappointed in not obtaining a particle of copper from it; they rejected it with the expression of a nick or copper nick, which name was then converted into copper nickel.

An English chemist found, by analysis, that the Packfong imported from China in the year 1821, but known in that country for several centuries, contained a large percentage of nickel; this discovery produced a revolution in the production of a composition in 1824, called in Germany Argentan, in France Maillechort, and in England German Silver (being first manufactured in Germany). This composition proved to be a substitute for the real silver and silver plate.

German silver in all forms and shapes was then manufactured on an extensive scale, and nickel ores were hunted up to furnish the pure metal, indispensable for the production of German silver. The United States and some European Governments thought it advisable to make use of nickel as a constituent of their small currency, which brought many millions of dollars into circulation. A few years later, in England and the United States, experiments were instituted by the silver-platers to replace the silver by pure nickel, which proved very successful, both in the expediency as well as economy. It will be seen, therefore, that nickel metal is destined to become of the greatest importance: for if we reflect for a moment to how many useful applications it has already been put, what immense consumption may be in future in store for it, and when we see how the political economy of the world must be affected by its increased uses, either as German silver, as coinage, or as substitute for silver plating, it is plain that millions of dollars' worth of sterling silver must in future be brought into circulation which formerly were locked up in the arts.

Nickel is contained in various proportions of the following minerals, distributed over many parts of the world, such as Sweden, France, England, Scotland, Chili, the Argentine Provinces, Westphalia, Saxony, Hesse, Thuringia, and Styria ; and in the United States, in the States of New York, Pennsylvania, Connecticut, Missouri ; and Canada.

The most prolific source for the production of pure nickel is from the following mineral substances :

1. From the smaltine, also called smaltite ; this mineral is properly cobaltiferous, being used in Saxony for manufacturing the smalts, zaffre and oxide of cobalt, and yields as a residue, after calcination, the substance called speiss, which contains 50 per cent. nickel ; this, with the following two minerals, yield the supply of nickel.

2. Copper nickel is an arsenical nickel, called by modern mineralogists niccolite, or arsenical pyrrhotite ; it contains about 45 per cent. nickel, and 50 per cent. arsenic.

3. Millerite, which is a sulphide of nickel, contains 65 per cent. nickel, and 35 per cent. sulphur ; it is found in two forms in nature, crystalline and capillary millerite ; it is found in capillary crystals, in cavities of other minerals, as at Antwerp, New York, with spathic iron, in radiated or fibrous crystalline forms, found in considerable quantities at the Gap mine, in Pennsylvania.

4. The Pyrrhotite, also called Troilite, which is, properly speaking, a sulphide of iron, in a massive condition, contains but a very small proportion of nickel, only from 3 to 6 per cent. ; it is nevertheless used as a material for extraction of nickel.

Pyrrhotite, also called nickeliferous pyrrhotite, is, on account of its abundance over the world, mostly employed—in Sweden, Norway, Spain, Cornwall in England, and in numerous localities in the United States, such as in Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Tennessee, and Canada.

Many more minerals are found in which nickel is associated with cobalt, copper, arsenic, antimony, bismuth, sulphur and iron ; but the most interesting occurrence is in the meteorite or meteoric stones which are occasionally thrown on the earth by celestial bodies, of various sizes, and which contain from 1 to 20 per cent nickel, and from 80 to 90 per cent. iron, with about ten other constituents of small percentage. Some of these masses are of considerable weight.

The specimen in the Smithsonian Institute at Washington, called the Tucson Meteorite, weighs 1,400 lbs.; one in Yale College weighs 1,635 lbs. Some masses, fourteen specimens in number, found in Texas, near the border of Mexico, a few years ago, weigh in the aggregate about 5,000 lbs., some from 3 to 500 lbs. each. I have in my own collection about twenty specimens, found in Tennessee, Wisconsin, Poland, Zacatecas, Mexico, and containing from 10 to 15 per cent. nickel.

The production of pure metallic nickel.—Several methods have been recommended by Berthier, Wohler, Liebig and others, for refining either the speiss or copper nickel; that of Liebig appears to be the more simple; the nickeliferous ore, whether it is speiss or copper nickel, is coarsely ground and roasted, and then mixed with half its weight of ground fluorspar, and this mixture is treated hydrochemically by adding three times as much of oil of vitriol in a leaden vat with gently heating, under constant agitation; the dry and hard mass is then broken up in small pieces and calcined in a reverberatory furnace, and then dissolved in hot water, whereby the sulphate of lime is removed; all the metals are now separated in the following manner: the mass containing the metals is dissolved in a mixture of sulphuric and nitric acid, and the solution left over night for crystallization; all the crystals are now dissolved, when the iron contained in the liquid is precipitated by a carbonate of soda; the second metal or copper is precipitated by passing sulphuretted hydrogen gas for several hours, and in order to separate the cobalt from nickel, chlorine gas is used to dissolve the oxide of nickel, leaving cobalt untouched.

The chloride of nickel may now be converted into sulphate or carbonate by the bicarbonate or caustic soda, or converted into sulphate of nickel and evaporated to dryness and calcined. In order to reduce the calcined salt to metal, it is mixed with charcoal and some flux as ground fluorspar and exposed to intense heat. When the regulus is left on the bottom of the crucible, it is sufficiently pure for all purposes of alloying, but by exposing the carbonate to a jet of hydrogen gas, the metallic nickel is obtained chemically pure.

The millerite from the Gap mine in Pennsylvania and the accompanying ore, the pyrrhotite, are now mostly operated on for the production of pure nickel. The first contains 63 per cent. nickel and 35 per cent. sulphur, the remainder being of iron, copper and cobalt; while the pyrrhotine contains but 6 per cent. nickel. These ores are treated either in the way just described, or by a late method proposed, which is the following: To mix the coarse powder with iron filings and nitro-muriatic acid, the solution evaporated to dryness, and then dissolved in water and treated with sulphuretted hydrogen for precipitating the copper; and after filtration boil with nitric acid, to deoxidize the iron; after diluting the liquid with much water, carbonate of soda is now employed, and the carbonate of nickel reduced in the manner described.

For making an alloy of the nickel metal, it is only necessary to evaporate to dryness the solution of sulphate of nickel, and then heating it at a high temperature, to reduce the oxide of nickel by charcoal at high heat.

There are several other methods recommended by Tupputti, Berthier and others, for procuring a pure metallic nickel from speiss or copper nickel, aiming mainly to the complete separation of cobalt and arsenic, which give much trouble, while the other admixtures of sulphur, copper and antimony, iron and manganese, may readily be separated. All the salts of nickel are protoxides; the salts are yellowish, and are decomposable by heat, though some exert a greater resistance than others; sulphuretted hydrogen gives no precipitate in acid solutions. The protoxide of nickel is obtained as hydrate by precipitating a salt of nickel with a caustic alkali; and calcination of the nitrate yields the anhydrous oxide, and is green when hydrated, and gray when anhydrous.

Chlorine forms with nickel both a hydrated and anhydrous compound. The first is obtained by evaporating the solution of the oxyde, as carbonate, in hydrochloric acid to crystallization; and the latter by passing dry chlorine over the metal heated to redness, or by slightly calcining the hydrated chloride. *Sulphate of nickel* forms green crystals, which lose transparency by gentle heat. *Nitrate of nickel* forms, likewise, bluish-green crystals, efflorescent in dry and deliquescent in moist air, soluble in water and alcohol, and gives with ammonia bright-blue, soluble crystals.

The *emerald nickel* is a native mineral found encrusted on chromic iron at Texas, Lancaster Co., Pa., and is a hydrated oxide of nickel.

Nickel metal has a white color, intermediate between that of silver and tin, has a lustre between steel and platinum, takes a high polish, is perfectly malleable, may be forged when hot into bars and hammered into plates when cold. It is very ductile, and may be drawn into fine wire. Its specific gravity is 8·28, and when forged, 8·7; conducts heat, obeys the magnet, and is itself capable of becoming magnetic, but it loses its magnetic property when heated to 350° ; it retains, however, the same whenever alloyed with arsenic.

The characteristics of the metal nickel were but little known in the beginning of this century, when it was thought to be a modification of *iron*, on account of its magnetic property ; while others supposed it to be an alloy of copper.

Nickel alloys.—There are three useful alloys with nickel :

1. The Meteoric Steel : it contains a very small proportion of nickel to steel ; it is extremely hard, susceptible of taking a high polish, and an appearance of damask, if treated with acids.

2. The German silver or argentan, or Chinese copper—Packfong.

This alloy has been known in China for several centuries, and many utensils were there manufactured of it ; but the composition was not known in Europe until the year 1821, when samples were brought to England and analyzed by Dr. Fyfe, who made known the contents, being 40 per cent. copper, 32 per cent. nickel, 25 per cent. zinc, and 3 per cent. iron. This information induced many manufacturers in England and Saxony to utilize the refuse from the cobalt mines in Sweden and Saxony for the production of the pure nickel, and particularly at the Royal Blue Smatt Works, where the speiss had been accumulating for several centuries and thrown away as useless. The imitation of silverware for the household was now begun on a very extensive scale in Sheffield and Birmingham, England, and Schneeberg in Saxony. Table furniture, such as tea, table and dessert spoons, forks and knives, German silver sheet and wire, and German silver castings for gun mountings were then introduced in market, in imitation of silver patterns, and very fine wares were brought from the manufacturers and exported to all parts of the world.

The price of German silver was regulated by the quantity of nickel which was consumed in the production of a good alloy with copper and zinc. The best mixture for white metal, in order to be rolled out in sheets and bars, was then made of 20 per cent. nickel, 60 per cent. copper, and 20 per cent. zinc, and in this proportion the writer began, in 1834 to 1839, to manufacture German silver in this city, for which purpose he imported from Germany many tons of the crude material and refined therefrom the pure nickel, producing a fine white metal, which was eagerly purchased by many mechanics. He himself received for several years silver medals from the American Institute at its fairs, exhibiting at one exhibition 150 different articles for the household, and knobs, hinges, stirrups, trumpets, napkin-rings, etc.

(To be continued.)

Franklin Institute.

Proceedings of the Stated Meeting, April 16, 1873.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the chair.

The minutes of the last meeting were read and approved.

The actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting held April 9th, 1873, the following donations had been received into the Library:

On the Short-Footed Ungulata of the Eocene of Wyoming. From Edward D. Cope.

On some Eocene Mammals obtained by Hayden's Geological Survey of 1872. From the same.

U. S. Patent Office Reports for the years 1869, 1870 and 1871. From the Commissioner of Patents.

Quarterly Weather Report of the Meteorological Office. From the Meteorological Committee, London.

Memoir of the Founding and Progress of the U. S. Naval Observatory. From Rear Admiral B. F. Sands, U. S. N.

Proceedings of the American Philosopical Society. From the Society.

Annales de Chimie et de Physik. From the Publishers, Paris.

Comptes Rendus Hebdom. des Séances de l'Academie des Sciences. From the Academy.

Moniteur Scientifique for 1870 and 1871. From M. Dr. Quesneville, Paris.

Bulletin Mensuel de la Société Chemique de Paris for 1870. From Chas. Barreswil, Esq.

Monthly Notices of the Royal Astronomical Society for February, 1873. From the Society.

Report on the Preservation of Wood, with tabulated results of the examination of all the best known methods; conducted by Dr. B. F. Craig, U. S. A.

Notes, Historical and Statistical, upon the Projected Route for a Ship Canal between the Atlantic and Pacific Oceans. From S. T. Abert, C. E.

Annales des Mines—January and February, 1873. From the Editor.

Annales des Ponts et Chaussées—January and February, 1873. From the same.

U. S. Patent Office Reports for 1868. From the Hon. Commissioner of Patents.

Journal of the Statistical Society of London for December, 1872. From the Society.

Journal of the Society of Arts of London for February, 1873. From the Society.

Notes on the Practical Gauging of Rivers. From Bvt. Brig. Gen. Henry L. Abbot, U. S. A.

Report of the Committee on Fire Patrol of the Chicago Board of Fire Underwriters. From the Board.

Report of the Fire Marshal of the Board of Fire Underwriters of the City of San Francisco. From the Fire Marshal.

Report of Progress for 1871 and 1872 of the Geological Survey of Canada. From the Director of the Survey.

Journal of the United States Centennial Commission. From the Commission.

Proceedings of the Academy of Natural Sciences, Philadelphia, December, 1872. From the Academy.

The Actuary further reported the passage of the following resolution by the Board of Managers, viz.:

"*Resolved*, That, in accordance with the recommendation of the Committee on Science and the Arts, the Scott Legacy Medal and Preminm be awarded to William Wharton, Jr., for his invention of a Safety Switch for Railroads."

The President then called for the reports of special committees. The Committees on the Horse-Power of Steam Boilers and on Conflagrations reported progress and were continued. The Committee appointed to fix upon a Factor of Safety in Carrying Steam Pressure, presented the following report:

"The Committee to whom was referred the inquiry for some rule for the thickness of shells of cylindrical steam boilers, ask to report: That the subject has been previously investigated by numerous writers, and the general conclusion appears to be that the 'factor of safety' is ordinarily taken at 6; or that the working pressure is not allowed to exceed one-sixth of the bursting pressure. Sir William Fairbairn derives as a result of his experiments on strength of materials and of joints: 'Wrought-iron plates with single rivetted joints = 34 000 lbs. per square inch tensile strain. as maximum average strength; and from these data finds the maximum working strength should be 5 668 lbs. per square inch.' Your Committee, from practical knowledge of the thicknesses usually assumed by the best boiler makers, think 6,000 lbs. more nearly agrees with American construction. As the factor of 6 is a large one, and as Fairbairn, in his value of 34,000 lbs., has made some allowance for reduction of strength in jointing, which may properly be taken as a part of the contingencies that the six should cover, the Committee believe that 6,000 lbs. can be safely taken for the basis of estimate of the working strength of cylindrical surfaces of steam boilers.

"Signed, ROBERT BRIGGS,
W. BARNET LEVAN,
W. F. DURFEE,
L. SCHUTLE, *Committee.*"

Upon motion, the report was accepted, and the Committee discharged from further consideration of the subject.

The President next announced a paper upon Bridge Building Considered Normally, by John Murphy, Engineer. The same will be found in full in the *Journal of the Franklin Institute.*

Dr. Robert E. Rogers next presented some remarks upon the proper manipulation of gases for the lantern, and exhibited and described an improved apparatus for this purpose.

Dr. Chas. M. Cresson offered some remarks upon the employment of the spectroscope in the laboratory, and exhibited in operation an improved and very convenient arrangement of this instrument for laboratory use.

The Secretary next presented his monthly report upon Novelties in Science and the Mechanic Arts.

Under the head of new business, Mr. S. Lloyd Wiegand presented the following:

"The rapidly increasing use of screwed tubing in steam and water apparatus, raises to importance the determination of the best proportions for, and means of producing screw-threads thereon.

"There is a want of uniformity in the pitch, or number of threads per inch, on tubes from different makers; also differences in the diameter of screws nominally the same.

"Difficulty and loss of time in screwing together parts supplied by different makers is not unusual, and badly fitted jobs are frequently chargeable to variations of standard and gauge.

"The extensive use of thin lap-welded tubing, originally designed for boiler flues for the water and steam containing portions of sectional steam generators, has within the last few years grown into a large business, as has also the employment of the same material for artesian well purposes.

"The threading of such tubes is limited in depth by the thickness of the material, and the sharp edged, or V shaped threads, when so applied, must be of very fine pitch to avoid weakening the tube below safe limits at the base of the threads.

"The fineness of pitch enforces a slowness in threading such tubes, and in tapping the parts into which they are screwed.

"A system of screw threads based on the same plan as that introduced by the Franklin Institute in 1866 for bolt thread purposes, appears to be specially applicable to tubing, in permitting the use of coarser pitches and preserving greater strength of the tubes at the base of the threads.

"If, in conjunction with this advantage a general unification of standard can be effected, a considerable saving of time and trouble might be reasonably expected to result from the introduction of such a system.

"In view of the above suggestions, the following resolution is offered:

"*Resolved,* That a special committee of five members be appointed by the chair, and announced at the next meeting of the Institute, to inquire into the expediency of introducing a system of uniform standard screw-threads for tubing, and if in their judgment it appears expedient, to report such a system to be recommended by the Institute to manufacturers for general adoption."

Upon the reading of the foregoing, Mr. Robert Briggs remarked that the work proposed by the resolution of Mr. Wiegand had already been very satisfactorily accomplished, and hoped the resolution would not pass. The Secretary moved that, in view of the absence of the mover, Mr. Wiegand, the action upon the resolution be postponed until the next meeting. Adopted.

Mr. Hector Orr then offered the following:

"*Resolved,* That a committee of three members be appointed to examine the plan and present working of the 'Committee on Science and the Arts' of this Institute, and report its defects, if any, and a remedy for the same; and that said committee now appointed shall consist of Mr. Coleman Sellers, President of the Institute; Mr. John C. Cresson, Chairman of said 'Committee on Science and the Arts,' and Mr. Frederick Fraley, Treasurer of the Institute; said special committee to have power to add to its number indefinitely, so far as such extension may tend to promote its object."

Mr. Robert Briggs gave notice that at the next meeting of the Institute he should move that Section 2d of Article XI of the By-Laws of the Institute, referring to the Committee on Science and the Arts, be abolished.

After some debate upon the subject, Mr. Orr withdrew his motion for the appointment of a Committee, whereupon the meeting adjourned.

WILLIAM H. WAHL, *Secretary.*

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EDITORIAL.

ITEMS AND NOVELTIES.

The Mills' Portable Engine.—The accompanying engraving illustrates an improved construction of portable engine, manufactured by the American Engine Company, of New York.

The engine is mounted upon wheels, adapting it to use for agricultural purposes, as well as for various other uses where a portable engine may be required.

The following description, condensed from the exhaustive pamphlet issued by the Company, will indicate its important features:

The cylinder, it will be observed, is placed at the upper part of the boiler close to the smoke-stack. It has an ample base with strong flanges, and held to the smoke box by well-fitting turned bolts; both head and nuts can be quickly reached with a common wrench. The smoke-box is an extension of the sheet forming the barrel of the boiler. The bolts attaching the cylinder not being placed in the steam or water space, are thus freed from liability to leakage. In this way, too, it is sought to avoid adding to the strain already within the boiler the strain of the engine when working. Instead of conducting the exhaust through elbows and tortuous passages, the steam makes but one turn, and that through a very easy curve.

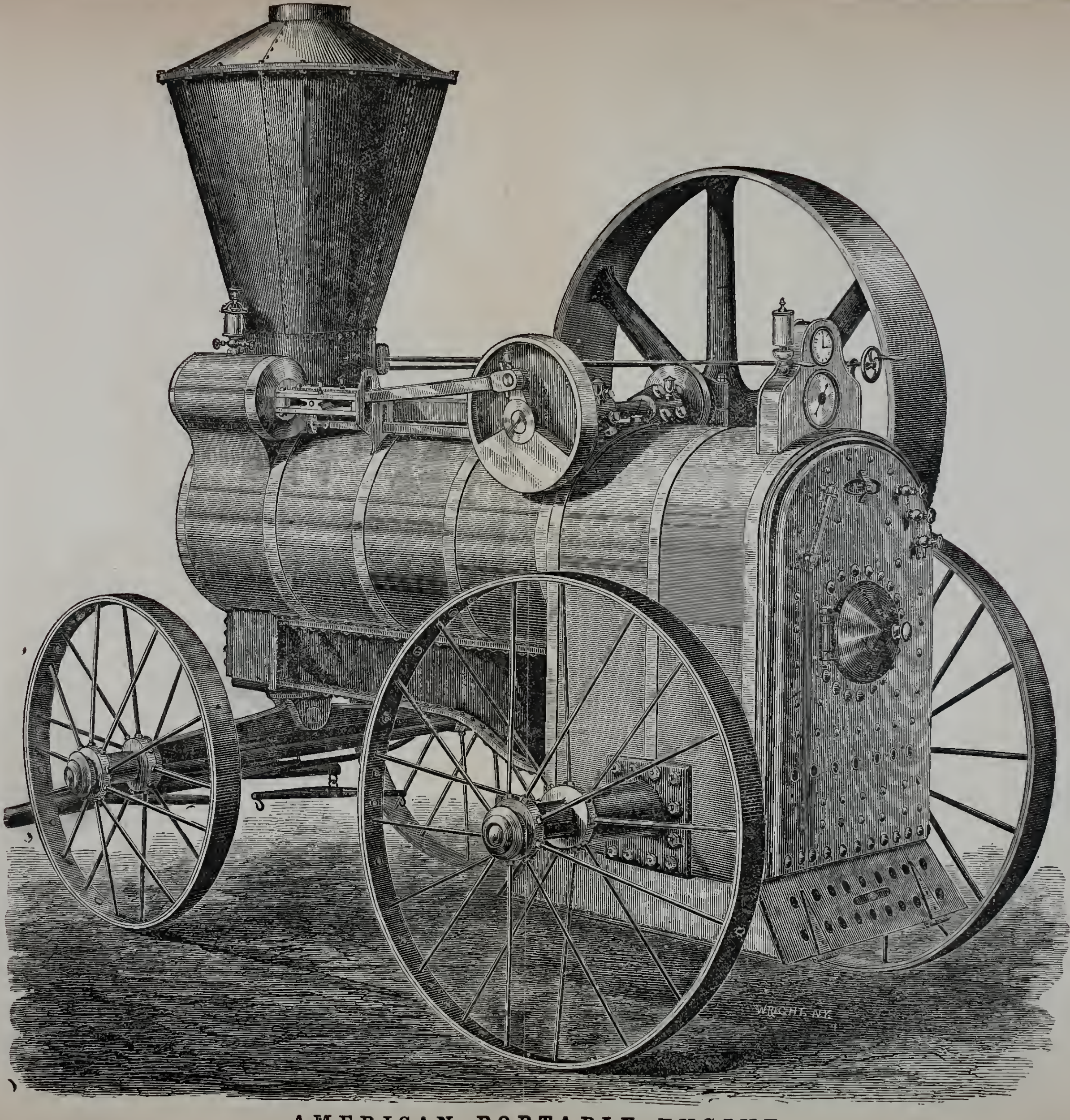
A steam dome of double the capacity usually furnished, is located within the smoke-stack, for which location are claimed several advantages, namely, that this is the nearest point to the cylinder which takes its steam, while the dome is jacketted by the smoke-stack itself, the heated waste gases passing through the dome, assisting in drying the steam. A governor is placed upon each engine, but is hidden on the engraving by other parts.

Beneath the bottom of the boiler will be observed a rectangular box, which represents the steam-water heater employed in this construction. This location is chosen as being the most convenient of access, and for putting the apparatus entirely out of the way. The cold feed water, on entering the heater, flows slowly three or four times over its whole length, in direct contact with the exhaust steam, by which process, it is declared, the water is heated much better than when steam only surrounds pipes containing water. It is also claimed that the heating of the feed water nearly to its boiling point, and permitting an appreciable time to elapse before supplying it to the boiler, a considerable portion of its universal impurities are separated, and deposited in the feed-water heater, by which the evils of incrustation are greatly lessened.

A few details of the construction of the engine will not be out of place.

It will be noticed that the engine is very low on the boiler, and this, with its general arrangement, adds greatly to its steadiness and accessibility. The main shaft is of the simplest form, being one single bar, with but one diameter—end to end. The two bearing boxes are cast to the saddle, that is, all in one solid piece, and cannot heat or bind from unequal expansion, nor from getting out of place. The crank wheel is not only forced on the shaft, but is also keyed. A collar for the shaft is made by the hub of the crank wheel on one side, and by the governor pulley on the other. The steam valve eccentric is secured to the back of the crank wheel, enabling the main bearings to be lengthened greatly beyond the usual length. The eccentric rod does not have the usual crook or offset, but is in direct line with the valve. The apparently excessive counter weight opposite the crank pin can scarcely fail to receive attention, but is claimed to be a construction approved by experiment as advantageous.

The shortness of the smoke-stack is also a peculiar feature of the engine, being only two and a half feet high, which is claimed to be sufficient. It will also be noticed that it is provided with ash pans.



AMERICAN PORTABLE ENGINE.

The fire box is deeper and combustion is claimed to be very perfect. The road wheels are of wrought iron, except the hubs. A broken spoke can readily be removed, welded and replaced. The tires are of steel, bolted on in sections.

These are briefly the chief points of interest involved in the construction of these machines. When the details of the tests, to which they will probably be submitted, are received, as promised, some notice of their performance will be laid before our readers.

The designer, Mr. E. W. Mills, writes that the experiments are now being made in air admission above the fire, and states that, thus far, its value seems to be that claimed for it by eminent engineers.

For these engines a number of advantages are claimed by the makers, of which the more prominent are great economy of water and fuel, a high efficiency as compared with their weight, simplicity of construction, and the advantage of the peculiar feed-water heater in reducing incrustation of boiler to a minimum.

The Durability of Railroad Ties.—A Dresden engineer proposes a method for increasing the durability of railroad ties, by which he considers they may be made to last four times as long as at present. The sleepers, of whatever kind of wood, are first dried in air, then in a hot chamber. They are next introduced while hot into an impregnating apparatus containing heated coal tar, where they are impregnated thoroughly under pressure. They are then coated with sifted sand or coal ashes, and allowed to dry. Every fissure is carefully filled; the nails used in fixing the sleepers are first dipped into hot coal tar, and any part of the work which is exposed is carefully covered. The inventor states further that wood thus prepared has also been used for house-building purposes, and with excellent results.

The International Bridge.—It is now expected that the great international railway bridge, to span the Niagara river between Buffalo and Fort Erie, will be completed, and a formal opening take place, some time in October next. It is the enterprise of an independent company, was commenced in May, 1870, and its cost will be something over one million dollars. The Buffalo "Commercial Advertiser" thus describes it:

"The superstructure is of iron, supported on stone piers, with the necessary draws for the passage of vessels. The length of the main bridge, across the river, is 1968 feet; thence across Squaw island to the west end of the bridge over Black Rock harbor, is about 1200 feet; and the bridge over the harbor to Niagara street is 517 feet. Squaw island is at present crossed by trestle work some twenty feet in height, but this is to be filled up so that the track across the island will be upon a solid embankment. The work of filling will not be done until the completion of the bridge, however, as the material is to be brought from Canada. Commencing at the Canada shore there will be nine spans across the river proper; three of them are 190 feet each in the clear; then come three spans, each 240 feet in the clear; then two draw openings, each 160 feet; then one span of 190 feet to Squaw island. The length of the bridge across Black Rock harbor, as before stated, is 517 feet, and in this will also be two openings of 90 feet each, with a pier between. The 'swing' over this opening, as well as that over the opening of the river, will be operated by steam, and the length of time required to open or shut the same is given at fifty seconds. The location of the swing in the river—nearer the American than the Canadian shore—is in accordance with the decision of a commission of United States engineers, appointed by the government, consisting of General Warren, Colonel Merrill and Col. Harwood, and the selection of the position meets the entire approval of the Canadian parties. Of the piers in the river, eight in number, all are finished save one in about the middle of the stream. In preparing for the foundation of this it was discovered that the rock in the bed of the river was covered to the depth of about nine feet with gravel. This it was, of course, necessary to remove. The work of removal has been finished, and the laying of the foundation will be immediately commenced. It is calculated that the pier will be completed in the course of three or four weeks. All the piers are so laid and built up as to secure the greatest solidity, and offer the least possible resistance to the ice. The depth of the water in the river where the bridge crosses is from ten to forty-three feet. The iron work for the Bridge is manufactured at Phœnixville, near Philadelphia, and the superstructure is known as the Pratt truss. The trusses consist of four main lines—that from pier to pier, the lower chord, as it is called; that parallel with it, but at a considerable height above it, and known as the main chord; and counter supports at either end, on which the upper chord rests. The upper chord and end counters are tubular, put together in five pieces, with flanges. The lower chord consists of rods which tie the counters and verticals, and resist the tendency of the upper chords to thrust the counters apart. The upper chord is that on which the roadway is hung. Transverse girders are suspended therefrom. The girders are bolted to the lower chord and connected with the upper by an iron vertical principal. The uniform load which would necessarily fall on this vertical principal is distributed laterally by means of counterbraces and rods, until it is thrown finally on the piers. The bridge has the strength of a tubular one, without its weight and other objections. Vertical and counterpieces form the sides; the tops of the vertical principals, united horizontally, strengthened diagonally, and supported by angle ties, form the roof, and the road way constitutes the floor. A novel plan is pursued in placing the iron spans upon the piers. They are built upon a frame-work over a number of pontoons, which act in the manner of a dry dock. The pontoons are carefully dropped between the piers, and when in position water is let into them, and the iron truss is settled into its exact place on the piers."

The chief engineer in the construction of the bridge is Mr. E. P. Hanaford, of Montreal, and the resident engineer is Mr. J. Hobson, of Fort Erie. The Grand Trunk, Great Western, and Canada Southern railways have already put down approaches to the bridge on the Canada side. The approach on this side is about 100 feet south of Parrish street, and here, also, several of the roads have already put down tracks, including the contemplated New York, West Shore and Chicago road.

A New Engineering Project.—A project of very novel character has lately been proposed by Captain Boudaire, and discussed before the French Geographical Society. It is nothing else than a proposition to create an interior sea in the desert of Sahara. A geodesic levelling made by the officer named, and calculations made on the differences of the levels as ascertained, have given promising results. The bed of the Mel-Rhir, a kind of salt marsh which covers a large extent of land in the province of Constantine, is nearly 27 meters below the level of the Mediterranean Sea. On its western side this bed inclines towards the east, having an inclination of 20 to 25 meters per kilometre; so that at 4 or 5 kilometres from its shore, the level is 28 metres below that of the sea. No serious elevation has been found between the series of lagoons, which extend far beyond the Tunisian frontier. The Geographical Society has called the attention of the government of Tunis to these results, asking to have a survey made between the Gulf of Gabes and Lake Faraoun, which terminates the series of interior lakes. If, as appears probable, this survey takes place, and if it establishes the fact that this lake is situated below the level of the Mediterranean, the possibility of creating an interior sea by the aid of a canal between the Gulf of Gabes and Lake Faraoun would be demonstrated.

Coal-Cutting Machinery in the United States.—An American coal-cutting machine, which has been for some time in operation in the Coal Brook Mines, near Brazil, Indiana, is described as follows:

It consists of a five-horse-power engine, worked by steam carried into the mine through an iron pipe, terminating in a few feet of rubber hose, and permits of the full motion of the machine. The design is to employ compressed air in place of steam as soon as the experiments are completed. The cutting arrangement is an iron rim, of four feet in diameter, which has on its periphery movable steel teeth, placed at points about twelve inches apart. These teeth can be removed and sharpened when they become dull. This rim lies on small wheels, which support it and allow a free motion, and has cogs on its under surface, which work into cogs on a shaft turned by the engine. By this means the power is applied near the circumference of the wheel, instead of at the centre, as in the ordinary circular saw. The principal reason for this arrangement is to get a deeper cut in the coal. The cutter can be put to a depth of three feet and a half, or seven-eighths of its whole diameter, whereas the ordinary saw can cut barely to one-half its diameter.

The machine runs on a movable track, and is fed by a screw working in cogs. The track is put down along the side of the coal, at a proper distance from it, and when a cut has been made the whole length, the machine is put on trucks and wheeled to the next room, where the track laying and cutting is repeated.

Its operation is spoken of as being in every way successful.

A New Tunnel Enterprise.—A tunnel is projected beneath the river Humber, in England, which shall be 2840 yards long. It will begin at Hessle, on one side of the river, and will terminate at Barton, in North Lincolnshire.

The Hoosac Tunnel.*—A contemporary reports the status of the work upon the tunnel for the month of July to be as follows: East end section completed December 12th, 1873; central section, heading advanced westward, 151 feet; west end section, heading advanced eastward, 137 feet. Total advance of headings during the month, 288 feet. Length opened from east end westward, 14,235 feet; length opened from west end eastward, 9,677 feet. Total lengths opened to August 1, 1873, 23,912 feet. Length remaining to be opened August 1, 1873, 1,119 feet.

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* Scientific American.

The American District Telegraph Company.—At the last meeting of the Franklin Institute there was described, and exhibited in operation, a system of telegraphing now about being introduced into Philadelphia, which, from its very great convenience, bids fair to become a decided favorite amongst business men, as well as to serve many useful purposes in the household.

The Hon. Daniel M. Fox, ex-Mayor of Philadelphia, introduced the subject to the attention of the members of the Institute, giving briefly a history of the gradual extension of the art of telegraphy to constantly increasing usefulness, and then explained the district system of telegraphy as follows:

This small iron box (showing it) contains a simple train of clock-work, which, when released and allowed to run, causes a small wheel, called a circuit wheel, to revolve, and when connected by wires with a battery and suitable apparatus, breaks and closes the electrical circuit a certain number of times, regulated by teeth cut in the wheel, thus indicating a certain fixed number. The wheels being different in numbers of teeth or notches, of course different numbers are communicated, and you readily see how invaluable this little box becomes.

As utilized by the American District Telegraph, the calls are given for a messenger, an officer or the Fire Department.

To explain more fully, the city is laid out into districts of about sixteen squares each. Near the centre of each district is located an office, from which wires radiate and are conducted to all parts of the district, running in and out of dwelling-houses, public buildings, stores, offices, factories, etc. The signal-boxes are connected with these wires, and in the district office the wires are connected with galvanic batteries, call-bells and self-starting Morse registers. The instant one of these boxes is operated upon, by merely pulling the ring projecting beneath, the circuit-wheel is allowed to revolve once, and its number is rung upon the call-bell, and recorded upon the strip of paper set in motion by the self-starting Morse register in the district office. The operator at once dispatches a messenger boy to answer the call. If the ring is pulled three times it indicates that an officer is wanted, and one is sent at once, accompanied by a messenger; if the ring is pulled more than three times in succession, fire is indicated, and the officer answers the summons with a fire-extinguisher, and the alarm is instantly communicated to the central office of the City Police and Fire Alarm Telegraph, and also the several fire engine and hose houses.

Thus it will be seen that electricity is to be reduced from its proud position as a messenger between continents to the humble uses of domestic life.

It is to be made an errand boy, to answer every household call.

There are thousands of little services which persons in moderate circumstances would gladly pay for at the rates charged by the Company, who cannot afford or do not desire to keep an errand boy or male house servant.

The American District Telegraph Company proposes to perform the messenger service indispensable among business men in a manner so thorough, expeditious, and cheap that the most entire satisfaction shall be given subscribers. A lawyer, banker or broker desiring to communicate with his client, or customer, touches the telegraphic key and instantly summons a trusty and swift footed messenger. A client at the office of his solicitor or financial agent, requires the services of a reliable person to bring or to carry valuable papers, or to perform any one of the thousand services which in a great city are in constant requisition. The telegraph places at his command and at moderate charge the trained servants of a responsible corporation whose interest it is that its patrons should be promptly and faithfully served.

A tradesman wishes to forward to his customer any article furnished, the telegraph permits him to do so without any inconvenience, thus oftentimes enabling him to effect sales because of the ability to promptly deliver goods purchased, which otherwise would have remained unsold. Thus the telegraph tends to increase trade, because it makes it easier of transaction by placing a supplementary corps of messengers at the disposal of both trader and customer, to do the bidding of either.

Physicians can avail themselves of it on communicating to their patients, sending medicines and procuring nurses.

Hotel keepers find that it not only saves an extra errand boy, but is also a great convenience to their guests.

A special feature of this system is to protect against burglary or fire. If a housekeeper is disturbed in the night by a noise of burglars in his house, he merely pulls the ring, and one or more policemen will arrive before the burglars have time to effect an entrance.

If your house is left vacant during the coming season, burglar attachments can be made with the instrument, and everything so arranged that the opening of a door or window is made known at once at the district office. A fire is discovered in the house; the alarm is at once given by pulling the ring as directed, and almost as soon as a bucket of water can be obtained in the house, men appear at the door armed with fire-extinguishers, accompanied by messengers, and in many cases will have extinguished the fire before the arrival of the fire department, which has also been summoned by the same agency.

In fact, there is no end to the use and convenience of our universal friend.

At the conclusion of Mr. Fox's remarks, a practical exhibition of the District Telegraph system was given, to the great interest of the members. Batteries and alarm boxes, with wires connected with the District office at Seventh and Chestnut streets, were put in the lecture room.

A signal was sounded for a messenger, and in about one minute a lad, dressed in uniform, rushed into the room with paper and pencil in hand, ready to deliver any message. A signal was then given for an officer, and also in a minute a conservator of the peace was in the midst of the audience, ready for duty. A fire alarm was then given, and in one minute's time appeared a man with a fire annihilator strapped on his back, ready to go into service.

These parties all came from the District office at Seventh and Chestnut streets, and did not leave there until they were summoned by the alarm-box, operated on by the speaker.

To Distinguish the Iodide of Silver from the Chloride, or from Embolite.—By JOHN C. TRAUTWINE, Civ. Eng.—The chloride of silver (alias horn-silver or cerargyrite) and also embolite are frequently mistaken by miners and others for the iodide of silver, alias iodyrite. Although in physical characters these minerals bear at times a considerable resemblance to each other, yet it is easy to detect the iodyrite by the following simple process, accidentally *stumbled upon* by myself: Mix a few drops of nitric and muriatic acids, and drop in a fragment of the suspected mineral. If it is iodyrite it will almost instantly lose its yellow color and its lustre, and become first brown and then black. Then it will again become yellow, and will be opaque, resembling a piece of yellow ochre. If the fragment is very small, say less than the head of a pin, or if in powder, these changes will take place within two or three minutes. If larger, a somewhat longer time will be required, and the acid close around the specimen will become slightly tinged with a delicate straw color. No such effects, nor, indeed, any appreciable others, are produced on either cerargyrite or embolite. The iodyrite does not dissolve in the mixed acids. Compared to cerargyrite, the iodyrite is a very rare mineral; and the former, when of a yellowish color, is sometimes sold to collectors for the latter, at high prices.

Mineralogical.—Some confusion has arisen in the designation of the two species, Amblygonite and Montebrasite, but the distinction has been clearly established by Descloiseau. In 1862 a mineral was discovered at Hebron, Maine, and referred to the species Amblygonite; in 1872 a mineral was found at Montebras, in France, and named Montebrasite. It has since transpired that the original mineral from Montebras is merely Amblygonite; but a second species has been found in this locality, to which the name of Montebrasite has been transferred, and it is now proved that the so-called Amblygonite from Hebron is really this true Montebrasite.

The matter, therefore, stands thus: Two minerals are found at Montebras, one called Montebrasite, the other Amblygonite; the former is also found at Hebron, in Maine, and the latter occurs also at Penig, in Saxony. Montebrasite contains lithia, but no soda, and also contains a notable proportion of water. Amblygonite contains both soda and lithia, but no water.

The Preservation of Iron Ships.*—By JAMES YOUNG.—My attention was called in January, last year, to the rusting of iron vessels, by observing that the bilge water of my yacht (the *Myanza*, 214 tons) was much discolored by red oxide of iron. Knowing that bilge water is apt to become acid, and thus to attack iron, the result was easily accounted for. Even when the water does not become acid we may expect some action on the iron to take place, when sulphuretted hydrogen exists there, as it frequently does. In this case, first a sulphide, then an oxide, and some sulphate are formed. The remedy seemed to be easy, because this acid can be neutralized by lime. The presence of this earth would also prevent the formation of sulphuretted hydrogen.

I put this immediately into practice, adding lime until the bilge water was alkaline, and samples were taken every fourteen days, which showed the amount of rust to be rapidly diminishing. After six months the liquid became perfectly clear, so that the cure was complete. The yacht is a composite one, and the action is therefore greater than in iron vessels generally, because of the copper bolts which are used. These bolts cause galvanic currents with the iron, and greatly assist its oxidation and solution.

As very little lime will last a long time, the plan causes neither trouble nor expense.

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The Bed of the Atlantic Ocean.—Thompson sums up the general results of the Atlantic soundings as follows: "In the Arctic Sea there is deep water, reaching to 9000 feet, to the west and south-west of Spitzbergen. Extending from the coast of Norway, and including Iceland, the Faröe Islands, Shetland and Orkney, Great Britain and Ireland, and the bed of the North Sea to the coast of France, there is a wide plateau on which the depth rarely reaches 3000 feet;

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* Iron.

but to the west of Iceland, and communicating doubtless with the deep water in the Spitzbergen Sea, a trough 500 miles wide, and in some places nearly 12,000 feet deep, curves along the east coast of Greenland. This is the path of one of the great Arctic return currents. After sloping gradually to a depth of 3000 feet to the westward of the coast of Ireland, in latitude 52°, the bottom suddenly dips to 10,000 feet at the rate of about 15 to 19 feet in the 100, and from this point to within some 200 miles of the coast of Newfoundland, when it begins to shoal again, there is a vast undulating submarine plain, averaging about 12,000 feet in depth below the surface—the telegraphic plateau. A valley about 500 miles wide, and with a mean depth of 15,000 feet, stretches from off the south-west coast of Ireland, along the coast of Europe, dipping into the Bay of Biscay, past the Strait of Gibraltar, and along the west coast of Africa. Opposite to the Cape de Verde Islands it seems to merge into a slightly deeper trough, which occupies the axis of the South Atlantic, and passes into the Antarctic Sea. A nearly similar valley curves round the coast of North America, and 12,000 feet in depth off Newfoundland and Labrador, and becoming considerably deeper to the southward, where it follows the outline of the coast of the States and the Bahamas and Windward Islands, and finally joins the central trough of the South Atlantic off the coast of Brazil, with a depth of 15,000 feet.

Dynamite.—From "Iron," we condense the following statement of the action of this explosive under various conditions, which throws some light upon the subject.

When dynamite is ignited by violent concussion, such as that occasioned by the detonation of a strong primer, it explodes, even in the open air, and if confined produces so great an effect that one part of nitroglycerin does the duty of ten parts of gunpowder. If inflamed in any other manner, without percussion, it burns quietly in the open air, and if confined may give rise to an explosion.

This explosion, however, whatever may be the temperature and the pressure to which the charge is submitted, is of a quite different character from the one above mentioned, its force being about twice that of gunpowder.

Hardening Steel.—Watch and clock makers and engravers harden their steel in sealing-wax. The article is made white hot and thrust into sealing-wax, allowed to remain a second, then withdrawn, and again inserted in another part, and this treatment is continued until the steel is cold and will no more enter the wax.

The hardness thus attained is extreme, and is comparable to that of the diamond; in fact, steel hardened by other processes may be engraved or bored with it, the engraving or boring tool being previously moistened with oil of turpentine.

Gilding Iron.—Sodium amalgam is said to be advantageous as a means of simplifying the method of dry gilding iron, and for painting gold designs thereon.

By simply rubbing with the amalgam, the surfaces of iron and similar metals, although oxidized, are at once amalgamated. Some solution of chloride of gold is then applied quickly on the amalgamated surface, and the mercury volatilized by the heat of a lamp or fire. A very uniform gilding is thus obtained, admitting of high polish. With silver and platinum salts similar results are obtained.

Chloroform in Analysis.—It appears that chloroform affords an excellent solvent and means of separation for many vegetable poisons, and hence is highly valuable in chemico-legal investigations.

For example: by shaking the solution, first made alkaline, with chloroform in the cold, the following are quickly and completely extracted: strychnine, quinine, quinidine, cinchonine, caffeine, theobromine, emetine, atropine, hyoscyamine, aconitine, veratrine, narcotine, codeine, nicotine and conine. More slowly are brucine, colchicine and papaverine taken up from alkaline solution; with the aid of heat sabadilline, and in small quantity narceine. Picrotoxine goes over to the chloroform far more easily from acid than from alkaline solution. Neither morphine nor solanine is taken up by chloroform. By shaking the alkaline chloroform solutions of the above bodies with dilute acids, the bodies themselves are obtained pure, leaving behind any fatty or foreign bodies in the chloroform. It is worthy of notice that a systematic process of separating these organic poisons, based upon these facts, has been devised.

An Improved Giant Powder.*—A new modification of dynamite, which has recently been patented by Mr. E. Judson, has the following constitution by weight:

Forty parts of nitrate of soda, six parts of rosin, six parts of sulphur, eight parts of infusorial earth and forty parts of nitro-glycerin.

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* Am. Artisan.

The nitrate of soda, rosin, sulphur and infusorial earth are separately dried and pulverized, and thoroughly mixed before adding the nitro-glycerin. Upon adding the nitro-glycerin, it is thoroughly stirred into the dry mixture until it is absorbed, forming a powder of uniform consistency.

It is claimed that this powder is more powerful than the mixture of nitro-glycerin and infusorial earth, the addition of the nitrate, rosin and sulphur increasing its explosive energy. It is further claimed that the only method of exploding it is by the use of detonating substances like fulminate of mercury, and that contact with a flame or concussion will not explode it.

Crystallographic.—The *Neues Jahrbuch für Mineralogie*, contains a paper from Prof. Vom Rath, of Bonn, upon some results of his studies with the crystals of the mineral leucite.

Every student of mineralogy is familiar with the beautiful icositetrahedral crystals of this mineral, which occur so plentifully in the lavas of Vesuvius ; and crystallographers have universally been accustomed to look upon them as characteristically isometric (monometric); so characteristic, indeed, that in the nomenclature of Haidinger, the icositetrahedron is called the leucitoid. Prof. Vom Rath has, however, been led, by a study of the direction of certain striæ on the trapezoidal faces of certain of these crystals, to the conclusion that they were not merely superficial markings, but really the edges of twin lamellæ, and as a result announces that the mineral must be transferred from the isometric to the dimetric system.

He asserts that the common crystals of leucite is really a combination of the 16 faces of the di-tetragonal pyramid, with the 8 faces of a primitive octahedron above and below these pyramidal faces. According to this view, the leucite is brought within the characteristic group of Vesuvius minerals crystallizing in the dimetric system, including zircon, humboldtilite, vesuvian, sarcolite, etc.

The Champlain Marbles.—The western part of Vermont, though comparatively small yet in extent, bids fair to possess the most extensive and beautiful, as well as the finest qualities and most valued varieties of marble of any part of the American continent. Its variety of color seems to be limitless, ranging from beds of pure white, through every conceivable intermediate shade or combination, to jet black.

These marbles, though known to exist for a number of years, have only lately been quarried, and something of their real extent and value made known. At present there are two quarries opened, one upon the shore of Lake Champlain, the other upon an island in the lake. The former covers an area of about 120 acres, the latter about three acres, and, from accurate examination, appear to be entire deposits of the richest variegated marble, of the closest and finest texture, susceptible of high polish, and admirably adapted for decorative architectural and other purposes. The facilities for transporting the marbles are excellent, and the demand for them is steadily growing.

The State Geologist, Prof. E. Hitchcock, speaks highly of the durability of these marbles, remarking that blocks of it taken from the naked ledge and sawed are found to be perfectly sound and unaffected by their long exposure.

This superb natural production must rapidly become famous the world over as an unsurpassed stone for ornamental and decorative purposes, and it has already been largely employed in these directions.

Test for Potable Water.—Good water should be free from color, unpleasant odor and taste, and should quickly afford a good lather with a small proportion of soap. If half a pint of the water be placed in a perfectly clean, colorless glass-stoppered bottle, a few grains of the best white lump sugar added, and the bottle freely exposed to the daylight in the windows of a warm room, the liquid should not become turbid even after exposure for a week or ten days. If the water becomes turbid, it is open to grave suspicion to sewage contamination, but if it remains clear it is almost certainly safe.

Recent Oil Discoveries.—Within the past few days discoveries of an unusually rich character have been made in the neighborhood of Titusville, Pa.

Quite a number of wells have been opened, producing from 600 to 1300 barrels der day. Well informed judges estimate the production of the new region at 30,000 barrels per day. So prodigious has been the flow, that, so it has been reported, the proprietors have scarcely been able to catch the liquid as it flowed from the pipes, and considerable quantities of oil have gone to waste.

Phosphor-Bronze.—The employment of phosphor-bronze for useful purposes in the mechanic arts seems to be slowly extending, though in the construction of ordnance it has not proved to be as satisfactory as was expected.

In France it has been employed by one house ever since its first production, three years ago, for the bearings of plate and general rolling mills.

The engine that drives the rolling mills in which it is used is about two hundred horse power, and the speed about sixty revolutions per minute. The rollers are 6.23 feet long and 2.03 feet in diameter, and weigh five tons. It was found that the gears, made of hard cast iron, broke frequently. These were at first replaced by ordinary bronze, then finally by phosphor-bronze.

The life of the ordinary bronze wheels did not exceed on an average five months, while those made of phosphor-bronze last about nine months.

When applied to bearings, the latter alloy is found to be equally superior to the former.

Editorial Correspondence.

NOTES FROM THE VIENNA UNIVERSAL EXPOSITION.

(From our Special Correspondent.)

Before I enter upon my descriptive report upon the technical, mechanical and other matters of importance connected with the Exposition, I find it necessary to call attention to the very greatly altered appearance of the plan of the several parts of the buildings and surroundings.

In consequence of the wonderful expansion attained by the Exposition, it has been found necessary not only to erect a great number of independent exhibition buildings and additions, but also to cover the greater portion of the courts or spaces between the cross galleries of the Industrial Palace, and employ the space thus economized to the purposes of the Exposition.

On this account, it has heretofore been impossible to obtain an accurate plan of the exhibition, and though the one published with a former report was at the time correct, it has long since ceased to be. It is therefore a matter of congratulation that the recent publication of the present plan of the exhibition, from official sources, has obviated this inconvenience.

The following plate is an exact copy of this official plan, in which the several parts and departments are indicated with numbers or letters.

For convenience in locating the different points of interest, this plan, conformably with the official one, is divided into zones.

The entrances are designated with +, and the spaces occupied by the several nationalities represented, are indicated by letters.

The plan is divided into four zones. Each zone has its own numbering.

For the technologist, the Machinery Hall affords, above everything else, the greatest interest. Of its dimensions I have already given your readers a report, and refer them to what has already been said in this particular.

The arrangements for transmission of motion were designed by the Engineering Bureau of the Exposition, and completed under the special care of Prof. von Grünberg.

The Commission had pledged itself to furnish steam and necessary machinery for transmitting motion, to the exhibitors of machinery.

As the plan of the Commission consisted in affording to each country represented separate arrangements for power, there was built for each country represented a separate boiler house (see the plate), with independent steam pipes; in addition to this each country furnished the necessary motive power to run its machinery, so that now there are in operation from England and Austria, each 4; from Germany, 3; from America, France, Hungary, Russia and Switzerland, each 1 —making in all 17 steam boilers, representing a total capacity of 600 horse-power.

The shafting is not continuous throughout the Hall, but for each nationality is only made long enough to meet the wants of the machinery there in operation.

The boiler houses, of which there are eight in all, were erected at the cost of the authorities; the boilers themselves, however, were supplied by exhibitors. The houses are open, and are furnished with chimneys of sheet iron, 30 meters in height. From the boiler houses the steam pipes pass separately into the Machinery Hall, the main steam-cocks being located where they are convenient of access. The arrangement for the discharge of the exhaust steam, as well as for feeding boilers, is very practical.

In the neighborhood of the Machinery Hall there is located a well-arranged machine and repair shop, which, both during the first arrangements of machinery, as well as at present, performs good service.

II Machinery Hall.
III Fine Art Gallery.
IV " Pavilion.
V Exhibition of Amateurs.
VI Western Agriculture Hall.
VII Eastern "
VIII Pavilion of the Jury.
IX Pavilion of the Emperor.
X Offices of the Exhibition Commission.
XI Post, Telegraph and Tax Offices.
XII Guard Houses.
XIII Buildings for Horse Show.
XIV Depot.
W Watch Houses.
A Water Closets
v Covered Passages.

First Zone.

1 American Restaurant.
2 Beer Hall.
3 Beer Hall of the Pilsener Brewery.
4 Hungarian Wine House (Czarda).
5 American Drinking Hall.
6 Pavilion of the "New Free Press."
7 Swiss Confections of Possard, in Zurich.
8 Pavilion of the Musical-Box Manufactory of Heller, in Bern.
9 Beer Hall of the Brewery in Siesing, near Vienna.
10 French Restaurant.
11 Pavilion of the Prince of Monaco.
12 Pavilion of the Finsponk Farm.
13 Swedish School House.
14 Swedish Military Exhibition.
15 Swedish Hunting Pavilion.
16 Gothic Mausoleum, by Wasserberger.

Agricultural Society.
48 Sanitary Pavilion.
49 Architectural Hall.
50 Italian Restaurant.
51 Exhibition of the Imperial Gardeners' Society.
52 Pavilion of the Iron Furniture Manufactory of Quittner & Herzoz.
53 House of Gardener.

Second Zone.

1 Light-house.
2 Fountain of Sultan Achmed II.
3 Triumphal Arch of the Nienerberger Tile Manufactory.
4 Russian Peasant House.
5 Pump-house.
6 Iron Church.
7 Swedish Farm.
8 Pavilion of the Imp. Hung. Forest Comm'rs.
9 Pavilion of the Steirmarck Forest Proprietors.
10 Saxon Peasant House } Siebenbürgen.
11 Szekler " } Siebenbürgen.
12 Austrian School House.
13 Vorarlberger Peasant House.
14 Austrian "
15 Pavilion for Glass Painting.
16 Sclovakisch Peasant House.
17 Croatian "
18 Roumanian "
19 } Gazdeler Peasant Houses (the neighborhood of
20 } Pressburg.)

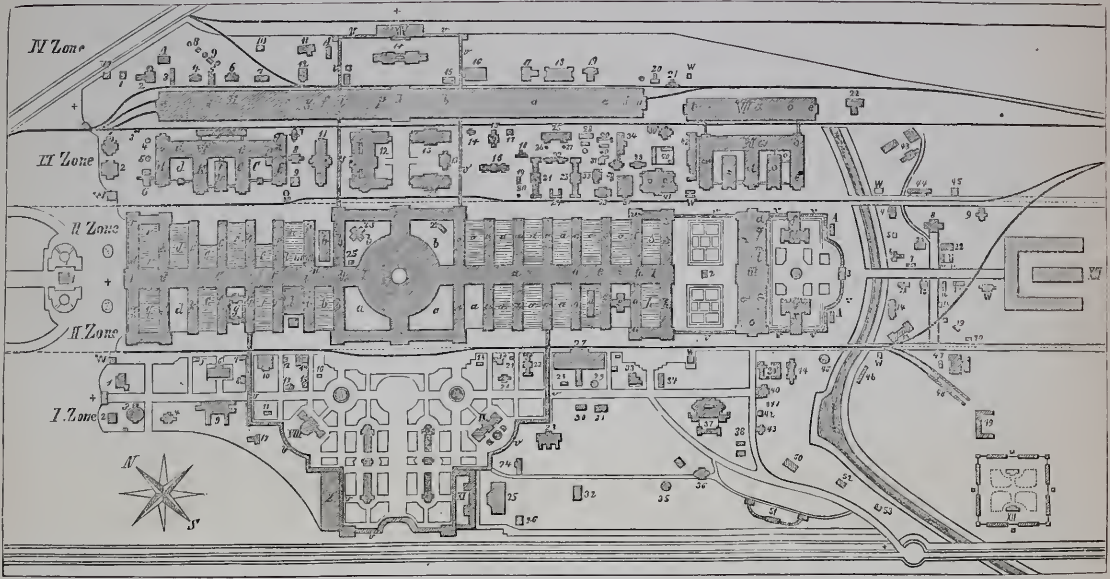
Third Zone.

1 American Restaurant.
2 Vienna Bakery.
3 English Workman's House.
4 Seed Pavilion.

35 Pavilion of the Stock Company for Construction of Bridges and Roads.
36 Tyrolean House (Wood-work Exhibition).
37 Additional Exhibition (Contributions to the History of Industry and Invention, and Pavilion for Women's Work).
38 Pavilion.
39 " of the Imp. Danube Steamboat Co.
40 Alsatian Peasant House.
41 Exhibition of the Imp. Agricultural Dep't.
42 Wine Hall of All Nations.
43 Sacher's Restaurant.
44 Pavilion of the Society of Promoting Forest Culture.
45 Pavilion of the Archduke Albrecht.

Fourth Zone.

1 Bakery of Heilfinger.
2 Coffee House.
3 American Boiler House.
4 English Workman's House.
5 English Boiler House.
6 English Workman's House.
7 French Boiler House.
8 English Gas Works.
9 Gas Company Limited.
10 Belgian Workman's House.
11 Machine Shop.
12 Swiss Boiler House.
13 Belgian "
14 Pavilion of Commerce.
15 German Boiler House.
16 Pavilion for German Tile and Ice Machines.
17 Austrian Boiler House.
18 Pavilion of the Northern Railroad.
19 " " North-western Railroad.
20 Boiler House for the Water Service.
21 Pavilion Ringhofer.



DIVISION OF THE SPACE IN THE MAIN EXHIBITION BUILDINGS.

a Austria.
b Germany.
c France.
d England.
e Russia.
f Italy.
g Switzerland.
h Turkey.
i Greece.
k Portugal and Spain.
l Belgium.
m Holland.
n Denmark.
o Hungary.
p Sweden and Norway.
q United States.
r South America.
s China, Japan, Siam.
t Persia and Central Asia.
u Egypt and Central Africa.
v Tunis and Morocco.
w Roumania.
x Northern States.
W Watch Houses.
A Water Closets.
v Covered Passages.

MAIN EXHIBITION BUILDINGS AND ADJUNCTS.

I Industrial Palace with the Rotunda.
II Machinery Hall.
III Fine Art Gallery.
IV " Pavilion.
V Exhibition of Amateurs.
VI Western Agriculture Hall.
VII Eastern "
VIII Pavilion of the Jury.
IX Pavilion of the Emperor.
X Offices of the Exhibition Commission.
XI Post, Telegraph and Tax Offices.
XII Guard Houses.
XIII Buildings for Horse Show.
XIV Depot.
W Watch Houses.
A Water Closets
v Covered Passages.

FIRST ZONE.

1 American Restaurant.
2 Beer Hall.
3 Beer Hall of the Pilsener Brewery.
4 Hungarian Wine House (Czarda).
5 American Drinking Hall.
6 Pavilion of the "New Free Press."
7 Swiss Confections of Possard, in Zurich.
8 Pavilion of the Musical-Box Manufactory of Heller, in Bern.
9 Beer Hall of the Brewery in Siesing, near Vienna.
10 French Restaurant.
11 Pavilion of the Prince of Monaco.
12 Pavilion of the Finspong Farm.
13 Swedish School House.
14 Swedish Military Exhibition.
15 Swedish Hunting Pavilion.
16 Gothic Mausoleum, by Wasserberger.
17 Boiler House.
18 Kiosk of the Southern Railway.
19 Kühn's Portable Dwelling.
20 Pavilion of the First Austrian Saving Fund.
21 Pavilion of Herr Stork.
22 Pavilion for Little Children
23 Restaurant of the Freres Provençaux (Paris).
24 Sala di Lettura } of Natale Biffi, of Milan.
25 Restaurant
26 Wine House
27 Iron Hall—Exhibition Hall for Metal Industry.
28 Pavilion of Austrian Mineral Springs.
29 " for Tobacco and Cigars
30 " of the Perlmose Cement Wares, from the Manufactory of J. Newnüller, in Nussdorf.
31 Russian Restaurant.
32 Steirian Dwelling House.
33 Russian Dwelling House.
34 Exhibition of the Austrian Lloyd.
35 Wigwam.
36 Iron Hothouse of R. P. Wagner.
37 Palace of the Viceroy of Egypt.
38 Small Japanese Buildings and Gardens.
39 Cercle Oriental of Dr. Hardt.
40 Turkish Dwelling House.
41 Turkish Bazaar.
42 Turkish Coffee House.
43 Persian Dwelling House.
44 Exhibition of the Imperial Minister of Marine.
45 Light-house of Saulter & Co., Paris.
46 House of the Photographic Association.
47 do. of the Agricultural Society.
48 Sanitary Pavilion.
49 Architectural Hall.
50 Italian Restaurant.
51 Exhibition of the Imperial Gardeners' Society.
52 Pavilion of the Iron Furniture Manufactory of Quittner & Herzoz.
53 House of Gardener.

SECOND ZONE.

1 Light-house.
2 Fountain of Sultan Achmed II.
3 Triumphal Arch of the Niederberger Tile Manufactory.
4 Russian Peasant House.
5 Pump-house.
6 Iron Church.
7 Swedish Farm.
8 Pavilion of the Imp. Hung. Forest Comm'rs.
9 Pavilion of the Steirmarck Forest Proprietors.
10 Saxon Peasant House } Siebenbürgen.
11 Szekler "
12 Austrian School House.
13 Vorarlberger Peasant House.
14 Austrian "
15 Pavilion for Glass Painting.
16 Sclovakisch Peasant House.
17 Croatian "
18 Roumanian "
19 } Gazdeler Peasant Houses (the neighborhood of
20 } Pressburg.)

THIRD ZONE.

1 American Restaurant.
2 Vienna Bakery.
3 English Workman's House.
4 Seed Pavilion.
5 Stand-pipe for Water Service.
6 Iron House of S. C. Hemming & Co.
7 Swedish Restaurant.
8 Norwegian } Fishing Apparatus.
9 Swedish
10 Norwegian Garden Kiosk.
11 German Pavilion of Instruction.
12 Germany's " for Industry.
13 German ? Industry Exhibition.
14 Eating House.
15 Pavilion of the Duke of Coburg Gotha.
16 " of Prince Schwarzenberg.
17 " Mauthner.
18 Stable Building of R. Ph. Wagner.
19 Curtis' Obelisk of Cement.
20 Houses of Artificial Stone.
21 Vorderbergen } Mining Industry Exhibition.
22 Innerbergen
23 Karntner
24 Pavilion of the Silberegg Brewery.
25 Machine Building Company (Prag).
26 Tar and Asphaltum (J. Bosch).
27 Architectural Ornaments of Zinc (Vinc Wenzel).
28 Steffen's Exhibition of Machinery.
29 Rothschild's Bridge Construction.
30 " Exhibition of Machinery.
31 Slate Exhibition of John Liebig.
32 Wooden Wares (Schubert).
33 Pavilion of the State Railroad.
34 English Restaurant.
35 Pavilion of the Stock Company for Construction of Bridges and Roads.
36 Tyrolean House (Wood-work Exhibition).
37 Additional Exhibition (Contributions to the History of Industry and Invention, and Pavilion for Women's Work).
38 Pavilion.
39 " of the Imp. Danube Steamboat Co.
40 Alsatian Peasant House.
41 Exhibition of the Imp. Agricultural Dep't.
42 Wine Hall of All Nations.
43 Sacher's Restaurant.
44 Pavilion of the Society of Promoting Forest Culture.
45 Pavilion of the Archduke Albrecht.

FOURTH ZONE.

1 Bakery of Heilfinger.
2 Coffee House.
3 American Boiler House.
4 English Workman's House.
5 English Boiler House.
6 English Workman's House.
7 French Boiler House.
8 English Gas Works.
9 Gas Company Limited.
10 Belgian Workman's House.
11 Machine Shop.
12 Swiss Boiler House.
13 Belgian "
14 Pavilion of Commerce.
15 German Boiler House.
16 Pavilion for German Tile and Ice Machines.
17 Austrian Boiler House.
18 Pavilion of the Northern Railroad.
19 " " North-western Railroad.
20 Boiler House for the Water Service.
21 Pavilion Ringhofer.

Civil and Mechanical Engineering.

ON THE THEORY OF STEAM GOVERNORS.

By Hugo Bilgram.

It occurs not unfrequently that theoretical views offered for the solution of practical problems are not confirmed by the results of subsequent experiments, simply because the originator of the theory in question omitted to take into consideration facts or conditions which are inseparably connected with the subject, and which seriously affect the practical result. In fact, inaccuracy of this character is almost the only cause that can be given for the disagreement of theoretical and experimental results, and is often committed purposely to simplify the otherwise complicated theoretical deduction. Sometimes, however, practice demonstrates the incorrectness of the suggestion unexpectedly, and the discovery of the error, which may lead to a correction and a more successful solution of the problem, is often difficult. The present article shall ventilate one such mistake, heretofore made in most treatments on the theory of steam governors, showing that a great number of failures in this branch of engineering could have been avoided by a more careful theoretical examination.

It is the function of the governor to regulate the speed of the steam engine so as to maintain its rate as near as possible to a standard, notwithstanding the accidental changes of the load, or of the steam pressure. Its principle is based on the opposite action of two forces upon an arrangement of levers, which are connected with the regulation-valve to accomplish its adjustment. One of these forces is a result of rotary velocity, as centrifugal force, or the resisting force of air or liquids against revolving wings, while the other is independent of rotation, and, in most cases, gravity or the pressure of a spring. The governor being so attached to the engine as to partake of its motion, any change of velocity will cause a change of the first mentioned force and disturb the equilibrium, and the one of the two forces whose momentum is greater after this change will effect a movement of the levers, which is transmitted to the valve, and thus regulates the admission of steam. If the construction of the governor is such that, by the movement effected by either of the two forces, their momenta are changed in a favorable proportion towards the weaker force, and that therefore, after a corresponding change of position, the latter will have comparatively increased thus much as to check a further adjusting action; then the governor is a static one. It will, for every velocity ranging between certain limits, occupy a corresponding position; it will rise when the speed is increasing, sink while the speed is decreasing, and remain stationary in the corresponding position if the speed is uniform. Most centrifugal governors that are now in use belong to this class. A governor is astatic when for one certain velocity the opposing forces will be in balance at any position of the governor, and hence a movement does not affect the relative proportion of their momenta. It follows that for no other velocity this arrangement will remain in any stable position, but will rise or fall as far as the construction allows it. The parabolic governor is among the number of those which answer to this condition. Some governors are so arranged that any movement alters the proportion of the momenta in favor of the stronger force. Their balance is evidently unstable, wherefore they are unfit for regulating speed, and only men of very superficial knowledge indulge in the doubtful glory of inventing such. It may be remarked here, however, that the centrifugal governor with crossed arms, and a number of others, in their lower position are anastatic, and should, therefore, by suitable stops, be prevented from ranging below a certain limit.

The speed-regulating qualities of the static and the astatic governors are decidedly different, and the following consideration will show which of them is preferable.

Before all things it should be remembered that in all steam engines the steam is admitted and operated periodically. On this account periodical fluctuations of speed at each stroke are inevitable, and they are evidently beyond the correcting influence of the governor. Moreover, as the governor corrects the speed by adjusting the amount of steam admitted at each stroke, its action cannot be anything but periodical. If the regulation is accomplished by throttling the steam, the throttle-valve offers but little resistance to steam that has a small velocity, and effects a successful throttling only while the velocity of the admitted steam is at its highest rate, or near so, that is, at or near the middle of the stroke. If variation of the expansion is the medium of regulation, the instant in which the cut-off takes place is the only time in which the governor exerts its influence upon the admission of steam. At any intermedial time, the governor may assume, at least inside of certain limits, any position, without in the least affecting the production of work. Any movement of the governor will therefore realize a change of the performance of work only at one certain stage of the stroke. This fact seems to have been heretofore invariably overlooked, in spite of its decided influence upon the theory of governors.

Because periodical variations are inseparably allied to the speed, and the velocities of the main shaft at different stages of a stroke are different, only those of corresponding stages can be compared for the determination of a change of speed, and the preceding shows that the governor complies with this condition.

Any change of the steam pressure or of the load will cause the speed of an engine to depart from the standard rate. In considering the thus produced abnormal speed, for the purpose of determining means of correction, two points are to be observed: Firstly, the character which shows whether the speed is uniform, increasing or decreasing, and which is the direct result of the relation between the produced work and the load, as the speed will be uniform when the amount of admitted steam is proportionate to the load, and inconformable when a disproportion is prevailing; and, secondly, the deviation of the rate from the standard, which is a secondary product of dynamical disturbances, being dependent on the duration of differences of previous occurrence. The distinction of these two points should be well regarded, for if they are confounded, what, indeed, only too often happens, the theorist is apt to be misled and to arrive at false conclusions. Inconformity of speed can be remedied by a single operation, by simply adjusting the amount of admitted steam until the disturbing difference is corrected. But, although by this process an acceleration or retardation of speed may be checked, yet the change of rate which does take place before the operation is completed will not be reversed, and hence the thus corrected speed, though uniform, will not have the original rate. The static governor is adapted for this regulation, and because the governors which are at present in use almost exclusively belong to this class, their most prominent peculiarities may be enumerated here. According to the principle of their construction, their position, and consequently also that of the regulation-valve, is directly dependent on their velocity. While the speed of the engine changes, the governor is operating, and it ceases its operation after the restoration of conformity of speed. A higher speed corresponds with such a position of the valve that the amount of admitted steam is small, and *vice versa.* There is a highest speed for which the regulation-valve is completely shut, or nearly so, and a lowest limit of speed at which the valve allows the fullest admittance of steam. The actual speed will vary between these two limits according to the work required. The smaller the comparative difference is between these limits, the more sensitive is the governor. Any static governor can be made more or less sensitive by changing the relation of the motion transmitted from the governor to the valve, so that a like movement of the former causes more or less adjustment of the latter. But when the sensitiveness is increased in this manner, the energy or capacity to overcome frictional resistance is diminished, and hence the increase of sensitiveness is somewhat limited. There is, however, still another limit of quite a different character, arising from the fact that the governor does not as instantaneously influence the production of work as it adjusts the valve, for a greater or smaller part of a stroke has to expire after a change of load before the adjustment becomes effective, and after this the effect of a continued adjustment becomes realized in successive moments following at intervals of the duration of one stroke. The first period, from the change to the first effect, as said, is only a fraction of a stroke, varying in each case, and therefore the first dynamical effect of the governor can be but incomplete, causing the correction of only a part of the difference. The remaining difference should be completely corrected after the lapse of the second period, which has the constant duration of a stroke. The sensitiveness of a governor should therefore be so selected that the change of speed caused by a given dynamical difference during the time of one stroke or of half a revolution of the main shaft, should effect such a degree of adjustment that this difference will just be removed. A less sensitive governor will after the second stroke leave the residue of the partly corrected difference for the third, and again a smaller residue for the fourth stroke, and so on, and will for this reason restore balance between work and load after a much longer period, which, in a strictly mathematical sense, is of infinite duration. Practically, though, the difference left after a number of strokes is so small that the correction can be regarded complete. If, on the contrary, the sensitiveness of a governor is greater, the actuated correction after each full stroke will surpass the required one, necessitating a reverse correction after the next stroke, which, though again being too great, leaves another difference, and therefore the completion of a correction will take a greater number of strokes, if not the surplus of correction after each stroke surpasses the original difference, in which case the restoration of balance is unattainable, similar as with the astatic governor, that will be considered further below. The above condition for the proper sensitiveness of a governor may be expressed by another formula of a more concise form. The inertia of the fly-wheel and other moving parts of the engine takes up and compensates any difference between work and load, and hence the change of speed per stroke is due to an increase or decrease of the dynamical equivalent of the momentum of inertia equal to the surplus or deficiency of the work generated during this stroke. This difference between the produced and the required work should be revoked by the change of speed taking place in the preceding stroke, and therefore the governor should constitute such a relation between the velocity and the position of the regulation valve, that the change of the dynamical equivalent of the inertia effectuates an equal but inverted change of the work generated during one stroke, or, in other words, that "the sum of the dynamical equivalent of the inertia of the moving parts and the work generated by each charge of steam is constant." Most static governors possess, however, a different degree of sensitiveness of different attitudes, and therefore should be so arranged that the mean sensitiveness of those attitudes in which the governor is used complies with the condition.

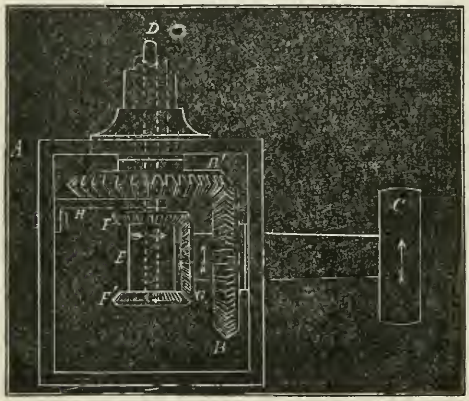
According to the above, a static governor, if correctly applied, removes any disturbance of balance in the shortest possible time, but allows a small difference in the rate of speed. Should it be required of the governor to correct not only the inconformity, but also this deviation, a double operation would be necessary. The adjustment which removes the disturbing difference must be extended further than would be necessary to merely restore the balance between work and load, in order to produce a new difference of the reverse character that would cause the rate of the deviated speed to return towards the standard. But before the latter is reached, a reverse action upon the steam-valve must be induced to retract the surplus of adjustment, and restore balance the instant when the rate of the previously disturbed speed again coincides with the standard. The astatic or parabolic governor has generally been recommended, even by authorities, for the accomplishment of this purpose, because by its application "the regulation-valve can assume and remain in any suitable position while the speed is at its normal rate." The question, though, is whether it will, not whether it can do so. The first action of this governor after a disturbance actually performs, as desired, an over-adjustment, because its tendency to rise or sink is limited only by the extreme positions of the valve, and lasts not only till the speed ceases to increase or decrease, but until a subsequent over-adjustment brought the speed back to the standard. It seems, however, the fact has entirely escaped attention that the second action which ought to reverse the surplus of correction at the instant when normal speed is restored, is not accomplished at all, and that instead of this the over-adjustment is kept up until it occasions another but reverse deviation, the correction of which will be attempted by the governor in the same manner but with a similar result, so that the speed will become alternately accelerated and retarded. The adjusting movement being limited only by the extreme positions of the valve, the latter, by the tendency of the governor, would at any occasion become entirely shut or opened, if it were not for the combined influence of inertia and friction, which prevent too sudden an action. On this account the over-adjustment is less than might be expected, and thus the severity of the fluctuations is somewhat retrenched.

A comparison is decidedly favorable for the static governor, and the allowance of a small difference of the rate for the purpose of gaining a more regular speed preferable to the attempt of preventing this difference of the rate and sacrificing the conformity of speed, without even attaining the end. Experience attests this theory, as parabolic governors are acting very vivaciously, now opening, now shutting the valve, even if the load is comparatively permanent; and they have been abandoned repeatedly, in spite of their recommendation by theorists, while static governors, for the sake of their steady and definitive action, always more or less have been a success.

The frictions which oppose the adjusting action prevent an instantaneous action of the governor. In general, it may be said that, on account of friction, the velocity can vary between two limits, which have for every attitude of the governor a definite value, without effecting the adjustment. Only after the velocity transgresses one of these limits does the action commence. It is evident that the governor need not partake in the periodical changes of speed which return with every stroke. If the change of speed that, on account of friction has no adjusting effect, is smaller than or equal to the periodical changes, this resistance prevents only a free play during each stroke, but allows a proper adjustment when the speed in the whole changes, because then the actual change of speed surpasses the change allowed by friction. Only if the friction has a larger momentum than that defined by the said condition, a delay of the operation is occasioned. Most modern improvements on the arrangement of the suspension-levers of the governor-balls purpose the attainment of a higher energy to overcome frictions in combination with a higher degree of sensitiveness.

The greater part of these frictions proceed from the throttle-valve, or from the arrangement by which the cut-off is varied, and therefore the stuffing-box of the former is generally left so loose as to allow some steam to escape, while cut-off arrangements, which can be adjusted by the feeble power of the governor, are very precarious or complicated. The automatic adjustment of link motion, or some other known variable cut-off valves, is sometimes desirable, but their regulation requires more power than the governor can afford. It would, however, seem curious if the engine builder, at the source of power, would be at a loss for so small an amount of it as is necessary for this adjustment, and therefore the thought lies near to use the governor, not as generator, but merely as a director of the adjusting power. To this end a combination of clutches, which receive their motion from the engine, may be so arranged that the governor only throws them in or out of gear, and they accordingly raise or lower the link or adjust the valve by the power of the engine. But no matter in whatever shape this plan has been tried, it invariably proved to be a failure, for after the engine had been started, the speed gradually run up to a point far above the intended standard, then fell off to a point below the latter, rose again, fell off, and so on, fluctuating in this manner between two limits, alternately rising and falling, and refuge had to be taken to the throttle-valve for the regulation of speed. The cause of this singular phenomenon can easily be accounted for. Although the governor used for operating the clutches may be of static construction, yet the arrangement, as a whole, possesses substantially the peculiarities of the static or parabolic governor, and its powerful action gives the fluctuations of speed due to over-adjustment, as described in the foregoing, a positive character. This will be clear by considering that the respective clutches remain engaged and active as long as the speed is below or above the standard, while it has been shown that the adjusting action ought to last only as long as the speed is increasing or decreasing, or as the balls of a static governor are actually rising or sinking. Being now acquainted with the cause of the failure, the question might be propounded whether the clutches can be so arranged as to make the operation accord with the latter condition. The answer is in the affirmative, for this end can be obtained by a combination in which the clutches are thrown into gear with the actuating power by the rising or falling movement of the governor balls, and in which, when the balls cease to rise or fall, the said clutches are immediately disengaged from the actuating power through the medium of a screw receiving its motion from the said clutches.

This device, which has recently been patented, can be carried out in various forms, one of which is represented by the accompanying sketch: *A* is a frame on which the governor is placed in the usual way, receiving its motion through the bevel gear, *B B′*, from the pulley, *C*. Rod *D* extends through the hollow shaft, and transmits the rising or falling motion of the balls to the block, *E*, which bears two miter-wheels, *F* and *F′*, ready to gear into the wheel *G*, that is fastened to and revolving with *B*. Block *E* is attached to the rod *D* by means of a screw-thread. Bracket *H* prevents rod *D* from turning. The rotary movement of block *E* is to be utilized for the regulation of the valve-adjusting devices. The application and construction of the receiver and transmitter of this movement is evidently dependent on the nature of the valve, and is therefore not indicated in the sketch, but may be conveniently placed in the space below block *E*. The operation of the arrangement is as follows: When rod *D* descends, clutch *F* will come in gear with wheel *G* and turn block *E* in the direction indicated by an arrow. This movement, however, does not only affect the adjustment of the valve, but also a rising of block *E* in relation to rod *D* on account of the screw-thread on the lower part of the rod, which causes a disengagement of clutch *F* from wheel *G* as soon as the downward movement of rod *D* ceases. A rising of rod *D* will have a similar effect in the opposite direction. But for the action of the screw-thread by which block *E* is attached to rod *D*, the actuating power would remain in gear until rod *D* returns to its original position, and the fatal over-adjustment would again take place.



Chemistry, Physics, Technology, etc.

LIGHTNING AND LIGHTNING-RODS.

By John M. Mott.

Read before the Meteorological Section of the Franklin Institute.

(Continued from page 127.)

A knowledge of the laws of electrical induction, accumulation and conduction, together with a clear understanding of the action and value of points, will enable us, without difficulty, to arrive at correct conclusions in relation to the application of lightning-rods to buildings.

The free electricity with which buildings are charged by induction will, in every instance, accumulate with the greatest intensity upon the ridges and gables, sometimes with greater intensity at one gable than at another. It is therefore absolutely necessary to place a point at each gable, to discharge the accumulated electricity there held by the opposite force contained in the approaching cloud; to place a point at each chimney or ventilator, to offer a line of superior conduction to that offered by ascending smoke, current of heated air or other gaseous matter; to connect all these points together with rods placed along the ridges, and also to connect them with the gas pipes, water pipes, steam pipes, speaking-tubes, or other metallic substances about the building. The more numerous the connections with the earth the better, not only to provide sufficient lines of conduction, by means of which we may so far neutralize the passing cloud as to prevent a disruptive discharge, but also to give the electrical agency an ample line of conduction, so as to prevent intermediate explosion during its transmission. As we depart from this system of applying rods the protection diminishes. Each ground rod should have several branches penetrating the earth to permanent moisture, and where it is difficult to obtain such a termination, they should be imbedded in charcoal. An improper termination of a lightning-rod is to connect it with the gas or water pipes of a city or village beneath the surface of the earth. Theoretically, it is the best possible termination; practically, one of the very worst. The gas and water pipes are not usually very far beneath the surface, but are, at the season of the year when thunder-storms are most prevalent, in comparatively dry soil. I presume the advocates of enormous earth connections, for the purpose of preventing electrical accumulation, would deem it unsafe to terminate a lightning-rod in such a soil, disconnected from the pipes. I have seen, in many instances, earth connections made with skill and care with both water and gas pipes. I have also seen rods so connected which had been disconnected by the workmen employed by the gas companies or by the city authorities, and either left in a dry soil or wholly disconnected from the earth. If there are gas or water pipes about the building, connect them with the lightning-rod on or in the building. Earth connections by means of such pipes become practicable if this plan of attaching be followed. The rod should also have independent earth connections made in the manner described. A lightning-rod has vastly superior power of conduction to that of the moist earth with which it is in contact, and will for this reason conduct the electricity which accumulates in such stratum, by induction, towards the cloud very rapidly, and in much greater quantities than most men are aware of. The experiment performed by Beccaria, mentioned in the Patent Office Reports on Agriculture for 1859, will be of interest to those who doubt the above conclusion.

If lightning-rods be applied to a building as directed, but terminated in dry soil, in case of a discharge falling upon the rod, damage would not necessarily ensue to the building or its contents. The earth might be thrown up from about the rod, and be scattered in all directions; this result is very often observed, and serves to demonstrate to some minds that lightning-rods are of value, as it furnishes evidence that the rods carried in safety charges which produced wonderful mechanical effects at their lower terminus.

If throwing up a little dirt would encourage the use of rods, I am not sure but it would be of value to the public to advocate a dry soil termination. This policy might, however, lead to disaster, in some cases; therefore we will demand, in every instance, that the rod be terminated in moist earth or imbedded in charcoal.

The conducting power of similar metals, of equal lengths, is proportional to the mass, and not, as frequently erroneously stated, to the surface; and in similar metals of the same sectional area and unequal lengths, it is inversely as their lengths. The form under which metal is placed does not change its conducting power, provided we retain the same weight or sectional area for a given length.

The experiment of Coulomb demonstrating that free electricity resides almost exclusively upon the surface of an *insulated* conductor has proved to be as much a stumbling-block to many electricians as the one fluid theory of Franklin, and his theory of the action of points upon electrified clouds. Since the molecules in the interior of a conductor discharge with equal readiness on every side, there is no chance for them to become charged; but at the surface of an *insulated* conductor the molecules have conducting molecules upon one side of them, and non-conducting molecules upon the other side, hence their polarization must be followed by the charged state.

If the insulated conductor be connected with the earth, or have a point attached to it, the free electricity will escape. A lightning-rod has one end imbedded in moist earth while the other is terminated in a point.

The conditions are not favorable to have much tension, except at the point, or liability to lateral discharge, as the rod is so situated that discharges from it must necessarily be from one or the other of its extremities. We know that the physical effect of electricity being conducted by metals is to generate heat, that the relative conducting power of metals is determined by noting the degree of heat generated while a given quantity of electricity is passed over wires of uniform size and equal length, made from the different kinds of metals, and that increasing the temperature diminishes the conducting power; hence it is absurd to claim that the conducting power of lightning-rods is proportional to the surface.

Trees near dwellings do not, as many suppose, afford protection; on the contrary, they increase the danger to persons or property in their vicinity and the necessity of using lightning-rods to prevent damage. They offer facilities for a direct discharge, consequently objects near them are in great danger from the return stroke. The fact that trees are injured by lightning is proof that they are poor conductors, while the large numbers of persons and animals annually killed near them by this same element is conclusive evidence that they do not afford the protection claimed.

In newly settled countries the cabins are usually provided with stoves, the pipes of which project through the roof; while these pipes do not in the least attract electricity, they furnish a path of less resistance than that of the surrounding air for its passage, the effect of which has often proved fatal to the occupants.

Barns are very frequently destroyed by lightning. This is owing to several causes: first, efficient lightning-rods have not been erected in a proper manner; second, the combustible material they usually contain and the comparative ease with which it is ignited; third, they are sometimes filled with hay or grain imperfectly cured or dried, and are also not unfrequently left during the season of thunder-storms surrounded by decomposing vegetable and animal matter. These substances ferment, or "heat," as the farmers term it, and as the gas or vapor rising from the mow or yard into the atmosphere above the barn furnishes a line of less resistance than the surrounding air, it becomes a part of the line of discharge when the cloud approaches sufficiently near so the electrical attraction between the opposite electricities can overcome the resistance.

The annoying and disturbing effects of lightning upon the telegraph are caused by conduction and induction. A charged cloud often covers a space of a hundred square miles or more, extending over lines of telegraph. The point of disruptive discharge may be at a distance of many miles from the wires. When the cloud is over the wires they become charged by induction, and when the discharge ensues, from any point, induction instantly ceases and the wires return, like other objects, to their normal condition.

The effect of this return is often observed upon the instruments when the operator is too far from the point of the discharge to see the flash or to hear the report.

Mr. Crosse, of Broomfield, England, has, by means of wires about one-third of a mile in length, insulated, and supported by means of poles and trees in his park, frequently succeeded in conducting from the atmosphere sufficient electricity to charge and spontaneously discharge a battery of fifty Leyden jars, containing seventy-three feet of coated surface, twenty times in a minute, accompanied by reports as loud as those of a cannon. Telegraph wires conduct free electricity from strata of charged atmosphere in the same manner as the suspended wires of Mr. Crosse, and as the insulators become covered with a thin film of moisture, by the condensation of aqueous vapor, they allow the electricity to pass from the wires to the poles, and as these are imperfect conductors the phenomenon of a disruptive discharge frequently occurs, attended with its well known consequences. If each pole had a wire extending its whole length, attached to it by means of a few small staples, such phenomena would be entirely unknown.

The free electricity from charged strata of air is frequently conducted by the wires into the office in such quantities as are sufficient to melt the fine wire of the instruments.

It is by making a practical application of our knowledge of the effect of points when attached to charged bodies, namely, increasing the intensity sufficiently to cause a free discharge at any given point, that the instruments and operators are preserved from destruction by lightning. The safeguard is composed of two toothed pieces of metal, disposed so that the teeth are nearly in contact. One of these pieces is attached to the wire and the other is in contact with the earth. If electricity is conducted from the atmosphere by the wire or accumulates upon it or the apparatus, by induction, it is given off by the points in contact with the wire to the piece which is in communication with the earth; disasters are thus avoided.

Oil tanks about the oil distilleries have been exploded; fires have ensued involving great loss, supposed to have originated by being struck by lightning. These tanks are immense air-tight vessels, with the upper portion in the form of a dome.

The lighter portions of these coal oils rise to the top of the dome. These volatile oils are very inflammable, and when mixed with air are as explosive as gunpowder. The atmosphere about the tanks is filled with gas from these oils. The iron tank being a good conductor, well connected with the earth by means of the pipes running to the distilleries, would be easily charged by induction in case a charged cloud should be near it. Its form is such as to secure the maximum amount of accumulated electricity. The tank itself will not offer the least possible attraction for the electricity of the cloud, while the free electricity with which it is charged, by induction, offers great attraction. If a discharge should occur, the inflammable gas about the tank would be ignited before the electricity would reach the tank, and the most disastrous oil explosion and conflagration would ensue, notwithstanding the fact that the tank has sufficient conducting power to conduct with safety every discharge of electricity which may fall upon it from now to eternity.

This tank, which seems, to persons not conversant with electrical laws, to be most safe from injury by lightning, is known, by those who are familiar with such subjects, and who exercise their reasoning faculties, to be exceedingly defective, and in imminent peril during the passage of electrified clouds. A rod of iron or copper, attached to the dome and terminating in a finely plated point, would be a part of the tank, and would perfect its construction. The tank would not now remain in a charged condition; hence there would be no attraction about it. The point would permit a flow of electricity from the earth towards the cloud, and would tend to prevent an explosion.

Oil tanks thus protected would not be injured by lightning. Electricity might pass between other objects in the vicinity, ignite the gas in the air, and in this manner explode the oil in the tank. We thus see while it is quite easy to prevent lightning striking the tank, it is quite difficult to prevent the oil it contains from being exploded from the effects resulting from lightning passing between other bodies, as two clouds.

To escape injury from lightning, protect buildings as herein directed and remain in them during thunder-storms. Keep out of cellars and avoid being near trees during the passage of electrified clouds. In case the gas or water pipes of a building are not connected with the lightning-rods, it is not safe for a person to remain in a position in which his body would become part of the line of least resistance between them. Beds should be removed from the walls. Persons in chairs should be in the centre of the room, and keep their feet off the floor.

Before the application of lightning-rods to vessels, by Sir S. W. Harris, the damages to ships was of frequent occurrence, the loss of life fearful, and the destruction of property immense.

In 1820 S. W. Harris attached copper straps directly to each mast and continued them to the copper sheathing on the ship's bottom. He thus had a continuous system of copper conductors extending from the top of each mast to the water. After a test of twenty-seven years, at the express command of the Queen of England, the honor of knighthood was conferred upon Harris, "in consideration of his very useful inventions."

Since this system of protection has been applied to vessels, in no instance has any damage ensued to a vessel or to a cargo, nor has there been a single human being killed or injured by lightning while on a vessel thus protected. This fact fully demonstrates the theory of non-insulation to be correct, and that lightning can be controlled.

Magazines for storing powder were injured and exploded by lightning in cases where they were without rods, as well as in cases where rods were used which were insulated from the building by being placed at a short distance from it or passed over or through glass, horn or other non-conducting substances. In no instance has a powder magazine been injured by lightning where the rod has been attached directly to the walls. Conductors have been thus applied to powder magazines for about one hundred years.

It must not be taken for granted that if a lightning-rod be erected without insulation no damage will ensue. Non-insulation is but one of the conditions requisite for safety. All the conditions must be complied with or safety is not attainable. I am of the opinion that the use of glass or other insulators upon rods, together with the theory that rods attract lightning, and protect an area the radius of which is twice the height of the rod above the plane from which it projects, has been the cause of bringing the use of rods into disrepute. These theories are contrary to the teachings of philosophy; are based upon erroneous principles; their application has fully demonstrated their falsity, and led to disastrous results.

The height a rod extends above a building has no influence whatever upon a discharge of electricity further than arises from the fact of its offering a path of less resistance than the surrounding air before the discharge takes place. It is for this reason, solely, that the rod is carried a short distance above the ridge of a building, and is projected above the tops of chimneys, ventilators, &c. It cannot be supposed for a moment that an agency which moves with such terrible velocity and irresistible force as lightning, could be arrested in its onward course and drawn aside by an insignificant piece of metal in the form of a lightning-rod.

If metal does possess this power of arresting lightning, the use of metallic eave-troughs, steam pipes, gas pipes, water pipes, speaking tubes, bell wires, bells, valleys on roofs of buildings, chimney tops, cornices, etc., in and about buildings, should be at once discontinued, as they may attract more electricity than they can carry off, as some ignoramuses have asserted.

The idea that metal attracts electricity is unsupported by any fact, and is absolutely at variance with the whole course of experience. Such an opinion has arisen entirely from assumption and a partial consideration of facts, or from superstition, prejudice or unadulterated ignorance.

Lightning-rods do not attract lightning. They have no influence whatever upon a thunderbolt after it has started, to restore the equilibrium. The height they project above the building is of but little consequence, providing they be kept *low enough* to withstand the storms.

There is no law governing the lateral extent to which a rod affords protection, this being dependent upon the form of the object to which it is applied and the position of the electrified cloud.

If a building or its contents be injured by lightning, it is solely because its owner has neglected to use well known means to prevent it. Should life be destroyed, in a building, by lightning, the owner or public officers having charge of it should be held responsible by law.

City authorities who will not permit the erection of wooden buildings within the fire limits, lest these structures might endanger the property of others; nor permit a building to stand, whose walls are supposed to be in an unsafe condition, ought not to permit any building to remain in such condition as to endanger the life and property of a neighborhood by lightning.

SUMMARY.

1st. Lightning-rods, as usually erected, do not afford much protection.

2d. Insulators, glasses, at the points of support, are of no use in any case; they destroy the most valuable influence of the rod, and may, under certain circumstances, be the cause of most terrific and destructive return strokes.

3d. The conducting power of lightning-rods is proportional to their solid contents, or sectional area, with similar metals of equal lengths, and not to their surfaces.

4th. A lightning-rod should have the conducting power of a copper rod one-half inch square, and perfect metallic union of all its parts. A rod made exclusively from copper wires, if of sufficient size, constitutes one which is perfect in theory.

5th. Sharp points for the upper termination of rods are necessary. Rods are of but little value without them. Points should be plated, to prevent oxidation. They are also of value when used at the lower terminus of the rod.

6th. It is necessary to place a point at each gable, chimney and ventilator; to connect all together; to connect the rod with metallic roofs, gutters, valleys, steam pipes, gas pipes, water pipes, speaking tubes and other permanent metallic bodies about buildings, and the more numerous the connections with the earth the better.

7th. The rod must be attached directly to the building, the closer the better. It must not be insulated by being passed through or over rings of glass, horn or other non-conducting substances, nor be placed at a distance from the object to be protected.

8th. Ground rods must have two or more branches penetrating the earth to permanent moisture; must extend below the foundation walls or the bottom of the cellar. In some instances, where it is difficult to reach moist earth, they must be imbedded in charcoal.

9th. Lightning-rods, constructed and erected in accordance with the foregoing principles, will afford full protection in the hour of danger, and their use is strongly urged as a necessary means of safety.

DECAY AND PRESERVATION OF TIMBER.

(By T. J. Cram, Col. U. S. Corps of Engineers, Bvt. Maj. Gen. U. S. A.)

(Continued from page 186.)

V. *The Observed Condition of the Timber after Treatment.*—As might be expected, I have given close attention to this subject, and submit the following conclusions, drawn from my own observations:

1. The albumen in the wood has been coagulated thoroughly.

2. The outer portions of the sticks, the sap wood especially, are thoroughly impregnated.

3. The inner or heart portions of the sticks that contained air, and little or no sap fluids, are not so well filled as the outer parts, the stuffing being abundant on the exterior, and gradually decreasing towards the centre, where there is little or no evidence of it.

4. That substance, whether it be "hydro-carbon" or "resiniferous," coming from the oil and solidifying in the pores of the wood, is apparent, but it does not seem to stop altogether the absorption of water, yet so little water is taken in after treatment that it does not penetrate beyond the carbolic acid of the oil which has entered the wood.

5. Deeper penetration and a larger deposit of the hydro-carbon in the heart wood of the sticks would have been obtained by more oil and more time for the treatment.

6. A given number, say twenty cubic feet, all in one stick, is far more difficult to treat than the same number cut up into small paving blocks, railroad ties or fence posts.

7. In the large straight grain sticks, the penetration was not so ready nor so abundant as in the cross-grain sticks, showing that the antiseptic enters in directions parallel to the fibres far more easily than transversely to them. It is for this reason that the shorter the stick (like paving blocks, ties and fence posts) the more readily it becomes saturated.

8. In our operations the strength of the timber was not impaired; it was found of greater rigidity after the treatment, and as much lighter

as was equal to the difference of weight of fluids expelled from the green water-logged timber and the substance taken in; it was, however, rendered a little more brittle; but, though the "co-efficients" of elasticity and rupture should be slightly diminished by the process, still the timber would be amply strong, laid in piers, docks and railroads.

9. Could we have framed the timber, by cutting all the notches and dovetails before treatment, it would have been better for the work.

10. It is clearly shown in my observations that it will not do to trust implicitly to samples of wood of small dimensions which have been submitted to the process, for facts to govern us in drawing inferences to apply to large sticks of timber, either for the quantity of the antiseptic imbibed, the amount of the hydro-carbon left in the pores, or for the strength of the wood after treatment, or its weight.

11. It is not yet being two years since commencing the treatment, and immediately putting the timber into the construction, it is impossible to give results that may be observed five years hence, at the expiration of the first period of seven years. The treated sticks are marked in the work with a double cross (× ×), and the untreated with a single (×), and they lie side by side similarly exposed to all circumstances causing decay. At the end of the first period a comparison carefully made will give us the data upon which to judge whether we shall realize anything of what we hope to gain by this great experiment.

12. The inflammability of the wood for the first season after treatment is somewhat increased, though not so much as to cause objection to it for pier constructions. In a hot summer day immediately after treatment, the timber having been turned from its bright clean color to a dirty, sooty brown or black, by the process, was disagreeable to the men to handle, but all complaints arising on this score were due more to imagination or carelessness than to any well founded cause.

13. The whole atmosphere at the work was impregnated with the odor of the tank and scattered piles of treated timber, which was undoubtedly a strong promoter of health to the workmen. I have never known a public work in a marshy influence employing from two hundred to three hundred men as free from malarious diseases to the men or from sickness of any kind. I attribute this remarkable freedom from ill health to the antiseptic influence of the impregnated atmosphere.

VI. *Quantity of Timber Treated. Time of Treatment. Oil Consumed. Cost of Treatment.*—The whole amount treated was 186,580 cubic feet, in sticks of the sizes already given in Chapter III. I intended to have more treated, but the apparatus could not be made ready before the constructing contractor had to commence putting in his work.

The time consumed for each batch was twelve hours, *i. e.*, from when it entered to when it left the tank; the amount of timber in the tank was on an average of 1,100 cubic feet.

When the timber was on hand in good supply, and the apparatus in good working order, and the men diligent, the amount treated in a month of twenty-six working days was 27,738 cubic feet. This is a fair measure of what can be done with large timber that is green and water soaked, in a single tank of the dimensions of the one used.

The quantity of oil consumed for the saturation of the timber in any given case depends on the kind of wood, the thickness and lengths of the sticks and the time taken for keeping the wood under the treatment. The heating of the oil is only continued until all the water and gases are expelled or cease to come over from the pores of the wood.

In our treatment of the *large wet and green, white and red pine sticks*, the oil consumed was one-half ($\frac{1}{2}$) gallon to the cubic foot of timber, on an average, throughout the whole. It cost, delivered at the works, 15 2-10ths cents per gallon. In working the apparatus, one foreman, at $150 per month, and four hands, at $75 each per month, required, making the hire of men to amount to $450 per month. Allow for wear and tear of machinery $75 per month, and for fuel $33.75 per month.

The expenses per month, therefore, amounted for oil, labor, wear and tear, and fuel, to $2,666.84. This divided by 27,738, the number of cubic feet treated, would bring the cost of treatment to very nearly 9·61 cents per cubic foot of the timber, without including the cost of the apparatus.

The apparatus complete, including shed, costs not less than $9000. I have no idea of the royalty paid the patentee. I find that on the whole job the contractor, after deducting the cost of the apparatus, could not have realized more than $1056.66 to cover the royalty, the interest on his outlay, his personal expenses for two seasons, besides what the machinery would be worth, after completing the contract for 186,580 cubic feet.

The contractor for treating the timber, from isolated locality, and being subordinate to the constructing contractor for the supply of timber, was put to expense and loss of time, which would have been saved under more favorable circumstances.

The estimate I have given furnishes the proper criteria to enable one to judge, if he has a given quantity of timber to treat, whether it would be best to purchase the right, construct the apparatus and do the work for himself, or to hire the authorized agent of the patentee to treat the timber by the cubic foot. The cost of treatment may be considerably diminished from the foregoing estimate by attending to what follows in the next chapter.

VII. *Improvements Suggested in the Apparatus.*—Having seen the working in the operations for two seasons, I am prepared to recommend:

1st. That the swinging crane, which was worked by hand for loading and unloading the cars, should be so arranged that the lifting may be done by the steam engine, thus saving the labor of two men, and keeping the engine employed, instead of resting idle half the time.

2d. The timber tank should be covered with a wooden shell, leaving space, however, between it and the tank to allow the water jets to play, in the "cooling off," and thus prevent a loss of heat by radiation, and effect a saving of both time and fuel.

3d. Instead of a full circle, give the timber tank a cross section, like Fig. 6, rounding, however, the lower corners; then less oil would be required to cover the batch, and the timbers could be separated by horizontal and vertical spaces (as in Fig. 6) by thin strips of wood or iron, leaving channels for freedom of circulation of oil all around each stick while heating; and by this shape, too, a large coil of steam pipe could be introduced, and less time occupied in raising the temperature of the oil to the required degree, which, however, should not exceed 290° or 300° F., for much above 300° F. would impair the wood fibre and distil over the oil.

4th. When there is a large quantity of timber to treat, there should be two timber tanks instead of one only, so arranged that while the oil in one is heating the other would receive its batch, and the hot oil from the first flowed into the second as soon as the time comes to cool off in the first.

5th. Put a valve into escape pipe ∂, to retard at pleasure the escape of steam.

6th. Use a ten-horse-power steam engine with a boiler commonly used with a twenty-horse-power steam engine.

With an apparatus thus improved, one engineer, two skilled laborers all the time, and occasionally a common laborer, could conduct the whole process.

I would also improve the *name* of the treatment. Instead of calling it, what it is not, "creosoting wood," I would designate it by what it really is, viz.:

Carbolic acidizing wood. The chemical tests applied showed that no creosote entered the pores of the wood in the process. If any creosote is found after the treatment, it must have pre-existed therein. Empty the pores and stuff the cells with creosote, and I venture to say the wood will sooner perish.

VIII. *Estimate of the Saving to the Government by the Carbolic Acidizing of the Timber at the St. Clair Flats Improvement.*—I will make the formulæ general, and apply them to this improvement as an example for showing not only the saving on this, but on any other work:

Let t be the first cost in cents per cubic foot of the timber delivered at the location of the apparatus; f the cost in cents per cubic foot of framing and putting the timber into the work, including, on renewing, incidentals thereto; c the cost in cents per cubic foot of the treatment.

We see in Table C, Chapter II, that timber similarly exposed and of like kind, and even of inferior quality, has lasted in Europe, after treatment by Bethel's process, 19, 20, 24, 26, 32 years, and then found as sound as ever; and at the present time all the information I can obtain proves those timbers perfectly sound. There is no knowing yet how much longer they will last. The prevailing impression is with some engineers who have examined them, that they will last until literally worn out. I have a right, therefore, to suppose or assume that the timber treated by the Seely process for the St. Clair Flats Improvement will endure for twenty-eight years before renewals will be required. If time to-come proves the assumption to be wrong, the mistake on this point must then be attributed to the circumstance of a decided difference yet to be found between the durations of treated seasoned and treated green timber. Be this as it may, twenty-eight years is the epoch of duration for the treated, and seven years for the untreated, before this will require renewal. Again, the government pays on its borrowed money an interest equivalent to six per cent. per annum, and in making an estimate involving borrowed capital, the interest thereon must be compounded in order to arrive at the true state of the case. Upon the basis now stated we have the following formula:

$$\left.\begin{array}{l}
\left.\begin{array}{r}\text{Cost in cents per cubic foot}\\ \text{untreated, for 28 years}\end{array}\right\} = 12{\cdot}276 \times (t+f) \\[1ex]
\left.\begin{array}{r}\text{Cost in cents per cubic foot}\\ \text{treated, for 28 years}\end{array}\right\} = 5{\cdot}112 \times (t+f+c) \\[1ex]
\left.\begin{array}{r}\text{Saving cents per cubic foot by}\\ \text{treatment, for 28 years}\end{array}\right\} = 7{\cdot}164\,(t+f) - 5{\cdot}112 \times c
\end{array}\right\}(3)$$

In the St. Clair Flats Improvements $t = 21$ 3-10ths cents; $f =$ 9 7-10ths cents; $c = 15$ cents. Substituting these in the last formulæ (3), we find:

Saving per cubic foot by treatment, for twenty-eight years = 145 4-10ths cents; or, the annual average saving in this epoch, 5 2-10ths cents on every treated cubic foot in the work, which contains 186,258 cubic feet treated; or, an annual saving of $9685.42 on the work in consequence of the treatment.

We shall never hereafter obtain this quality of timber, nor get it framed and put in the work for less than 21 3-10ths cents for t, and 9 7-10ths for f. But I am confident, with the improvements I have suggested in Chapter VII for the apparatus, the cost could be made less than fifteen cents for c, unless the oil should advance very much in price above 15 2-10ths cents per gallon.

For determining the limit of c, above which it would not be profitable to treat the timber, we have the expression $7{\cdot}164 \times (t+f) - 5{\cdot}112 \times c = 0$; from which we find $c = 1{\cdot}4014 \times (t+f)$; *i. e.*, when the cost per cubic foot for the treatment is *one and four-tenths* the cost of the timber and the labor of framing and putting it into the work, there would be nothing gained by the treatment. This simple rule applied to St. Clair Flats Improvement, gives the limit of c equal to 43·4 cents.

IX. *Question of Applying the Seely Process for Preserving Timber to all hereafter to be used in Repairs, Preservation and Construction of Piers, and Breakwaters on the Lakes.*—If these works are to be kept up in good serviceable shape by appropriations from the national treasury, as ought to be, it will be in place here to briefly present the measure of the economy of this question; also the practical method of effecting this object.

There would be no necessity of treating any of the timber except that above water, and which I call the "superstructure."

In all the harbor piers, breakwaters, etc., upon the lakes, there are probably fifteen miles or more in extent of superstructure. The width will average at least eighteen feet, and height five feet, or five timbers above water. Experience has shown that they should all be planked over. To every running foot pierwise the superstructure will contain at least twenty cubic feet of timber on an average of all the works. In the fifteen miles, therefore, there are 1,584,000 cubic feet exposed to decay and requiring renewal. In periods of seven years to each work, its proportional part of this should be renewed. This estimate does not include the new works to be commenced hereafter, but the formulæ may be applied to them as readily as to existing work.

In every renewal of timber in the superstructure there is attendant or incidental labor of $2 per cord, for removing and replacing the stone filling without waste, in order to put in the new timber. This incidental item I find averages six and a quarter cents to every cubic foot of timber in the superstructure. Again, the cost of the iron drift bolts and spikes has to be again incurred at every renewal. I have made several attempts to save the old bolts and spikes, but the expense of pulling, straightening, etc., has proved more than they are worth. In the superstructure there is just about one pound of bolts and spikes to the cubic foot of timber, which at present prices costs not less than 4 1-6th cents, which is another incidental expense at every renewal. Since we have these for every cubic foot of the timber, we may add them to the cost of framing and putting in the timber, which will never be less than ten cents per cubic foot on an average. Putting the three foregoing items together, we shall have $f = (10 + 6\frac{1}{4} + 4\ 6\text{-}10)\ 20{\cdot}85$ cents.

The untreated square timber itself will cost, provided the plans be made as they should be, to require sticks not to exceed twenty-four feet in length, twenty-one and a half cents on an average delivered at the works, or first delivered at a properly selected place, which I shall name, for the location of an apparatus for treating all the timber before sending it off to the several harbor piers, for the renewals. Hence, we may put $t = 21\frac{1}{2}$ cents.

The treatment of the timber, including royalty for the patent, would probably cost eleven cents per cubic foot after the apparatus is constructed.

The total cost of the apparatus, improved as I have suggested, including preparation of the "Timber Bay," to receive the green timber before treatment, need not exceed $12,000, which, divided by the whole number of cubic feet to be treated, would be very nearly 76-100th cent per cubic foot. This item is chargeable to the account for treatment.

Again, the cost for freighting the treated timber from the site of the apparatus to the several harbors where the timber would be used would average $4 per thousand, board measure, or 4 8-10ths cents per cubic foot. This is another item chargeable to the account of the treatment.

Bringing the last three items together, we shall have

$$c = (11 + 0{\cdot}76 + 4{\cdot}8) = 16{\cdot}56 \text{ cents.}$$

By substituting the foregoing values for t, f, c, in the formulæ (3), we shall find the saving by the treatment, for an epoch of twenty-eight years, to be 218·74, or 7·81 cents annually per cubic foot, which, applied to the whole amount, would bring the whole saving to amount annually to $123,710.40, in consequence of the carbolic acidizing by the Seely process.

NOTE.—If, on a careful summing up from the records in the Chief Engineer's office at Washington, there should be found more or less than fifteen miles of such piers and breakwater constructions, this estimated amount of saving can be modified proportionally.

The best site the government could select for establishing the apparatus for treating the timber is at Fort Wayne, near Detroit, where there is an excellent harbor, a good United States engineer dock already; also, extensive river front for making the "Timber Bay," and plenty of ground, all belonging to the United States.

If two such places should be deemed advisable, probably Green Bay, Wis., at or near the site of old Fort Howard, would be the most advantageous place on Lake Michigan.

All of which is respectfully submitted,

T. J. CRAM,

Col. ret'd Corps Eng'rs, Bvt. Maj.-Gen. U. S. A.

To Brig.-Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A.
Detroit, Dec. 15, 1870.

NEW YORK, *Dec.* 10, 1870.

Brig.-Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A., Washington, D. C.

GENERAL,—After careful inquiry concerning the various methods of preserving timber from decay, and from the attacks of land and marine insects, now practiced, I am convinced that the *Bethel* process, patented in England in the year 1838, and the two American modifications of it known respectively as the *Seely* and the *Robbins* process are both cheaper and more effectual than any other preservative methods now in use.

They consist in impregnating the timber, to a greater or less degree, with carbolic acid contained in the creosote of coal tar.

By the *Bethel* process, the timber is placed in an air-tight cylinder of boiler iron, which is then exhausted of air to the point indicated by 20° on the Bourdon vacuum gauge. At this point the creosote is admitted into the cylinder at a temperature of about 120° Fahr., at once filling it to within an inch or two of the top. A pressure of about 150 pounds per square inch is then applied, and maintained for from five to eight hours, depending on the size of the pieces of timber under treatment. The creosote is then drawn off and the timber removed.

The *Seely* process, in brief, consists (1) in subjecting the wood to a temperature above the boiling point of water, and below 300° Fahr., while immersed in a bath of creosote oil for a sufficient length of time to expel the moisture. When the water is thus expelled the pores contain only steam, and (2) the hot oil is quickly replaced by a bath of cold oil, by means of which change the steam in the pores of the wood is condensed, and a vacuum formed, into which the oil is forced by atmospheric pressure and capillary attraction.

Six to twelve pounds of creosote oil to the cubic foot of wood is expended in this process; the amount depending upon the use to which the wood is to be put. For piles or other timber exposed to the depredation of worms, twelve pounds is used.

For gun platforms it is thought that nine or ten pounds will be sufficient. An impregnation of ten pounds to the cubic foot costs 25 cents. For piles the usual charge is 30 cents per cubic foot.

At 25 cents per cubic foot, the cost of curing the 15-inch gun platforms, of the design recently sent to the Chief of Engineers, would be about $108 for each platform. The quantity of timber in these platforms may, perhaps, be somewhat reduced.

The Robbins process consists in treating wood with coal tar of other oleaginous substances in the form of vapor. The wood is placed in an air-tight iron chamber, connected with which is a still or retort over a furnace.

When heat is applied the vapor of naphtha is generated at 250° to 300° Fahr., the creosote oil vapor at 360° to 400°, and the heavier tar oils at 500° to 600°. The wood is thus exposed for from six to twelve hours, when the curing is considered complete.

By the Robbins process, it is impossible to charge the wood with more than a small fraction of the amount of carbolic acid, and the other component parts of coal tar, habitually expended in the Seely process. The Seely process appears to be, and is claimed to be, an improvement on the parent process of Bethel, to which we are obliged to refer for all evidences of the durability of creosoted wood.

It will cost $8.00 per thousand feet, board measure, to get timber treated by the Robbins process, or about $42 for each 15-inch gun platform.

I am not prepared to recommend this process, it being by no means certain that evidences of the value of the Bethel process apply to the Robbins modification of it, but they do apply, in my judgment, to the Seely process.

The parent process of Bethel is not practised in the United States.

My reply to that portion of the Department letter to which this communication refers is, therefore, that the most approved wood preservative process now practiced in the United States is known as *Seely's*, and that by it the front pintle wooden platforms for 15-inch guns, after the design recently forwarded by me to the Chief of Engineers, may be treated at a cost of about $108 each, and that the quantity of timber in those platforms may, perhaps, be safely reduced to such extent that the cost of creosoting will not exceed $100 per platform. A platform for 120° traverse contains 375 cubic feet, and one for 140°, 427 cubic feet.

This takes no account of foundations, which may be of either stone, concrete or timber.

I believe that a wooden platform, *thoroughly creosoted*, would last twenty to thirty years, and be better than a stone platform during that entire period. I think it is very important, and indeed essential, that the wood should be completely saturated with creosote at the moment when the temperature of both is above the boiling point of water, in order to secure the best results.

Very respectfully, your obedient servant,

Q. A. GILLMORE, *Major of Engineers, Bvt. Major-General.*

ON THE MOLECULAR CHANGES PRODUCED IN IRON BY VARIATIONS OF TEMPERATURE.*

By Prof. R. H. Thurston.

1. To determine with accuracy what are the molecular changes which are produced in iron by variations of temperature, and of other physical conditions, it should be first ascertained, by experiment and observation, what are the normal relations of the molecules, and, afterward, by similar means, in what way and to what extent, those relations may be naturally or artificially altered.

So much having been done, the investigation of the changes in the mechanical properties of iron, which result from these molecular changes, is a secondary research, and should naturally follow the preceding, as its sequel.

The almost insuperable difficulties which are encountered in attempting to deal with particles of seemingly infinitesimal dimensions, and with intermolecular spaces of immeasurably minute extent, have, as yet, prevented a satisfactory prosecution of the first part of the investigation by even the ablest physicist, and the second division of the subject still remains as a problem only partially solved, notwithstanding the fact that a considerable amount of experiment and discussion has thrown light upon it.

2. The following may be considered as a statement of the most generally accepted views of the molecular constitution of matter—views which are usually considered to most fully accord with observed phenomena.

(1.) All matter consists of indefinitely small parts, having dimensions and forms which are unchangeable by finite power, and which are endued with the properties of impenetrability and inertia.

(2.) These "atoms" are separated by spaces which are absolutely very small, but which are immensely great in comparison with the atoms themselves.

(3.) Several atoms, when united by chemical force, form a molecule, and aggregations of molecules, with intermolecular spaces, make up the masses of all matter.

(4.) Forces, both of attraction and repulsion, exist between atoms and molecules. These forces vary, in intensity, with changes of distance between molecules. The resultant of these sets of forces is sometimes attractive and sometimes repulsive, changing at times, and under definite conditions, from the one direction to the other. There may thus be exhibited several alternations of attraction and repulsion within a very minute range.

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* From "The Iron Age."

(5). At sensible and measurable distances the attractive force varies inversely as the square of the distance between the centres of attraction, and is termed gravitation.

(6). Gases manifest repulsion only in a degree which, in "permanent," or perfect, gases, varies inversely as the volume of the mass.

Liquids exhibit a perfect equilibrium of attractive and repulsive forces, but offer immense resistance to the disturbance of that equilibrium, by effort to reduce their volume appreciably, and less, although still considerable, resistance to its disturbance by increase of volume.

Liquids, however, offer exceedingly slight, and sometimes immeasurably slight, resistance to change of relative position of their particles, which, therefore, move more or less freely among each other, according to the greater or less viscosity of the liquid. They thus offer little or no resistance to change of form.

Solids are composed of aggregated molecules existing in the same condition of equilibrium as is seen in liquids, and offering similar resistance to change of volume, but they differ from liquids in exhibiting resistance to change of form, which resistance can usually only be overcome by actual destruction of cohesive force. This peculiar condition is the result of that form of force which has been termed "polarity."

(7). These three forms of matter are not distinctly separated from each other, but the same substance may pass, by gradual change, from one to another of the several classes, and may, in its ordinary state, exhibit such physical characteristics as to make it difficult to determine to which of two classes it is to be assigned.

In addition to the above it may be added:

(8). Solid bodies offer a resistance to change of form, which, within narrow limits, is proportioned to the magnitude of that distortion.

Beyond these limits the force producing change of form soon separates the atoms completely, by overcoming gradually the inter-atomic forces, and rupture takes place.

3. The last principle was discovered two centuries ago by that wonderfully acute philosopher, Robert Hooke, who published in 1678 his now well-known law, "*ut tensio sic vis.*"

The first seven of the preceding principles embody the general theory of Roger Joseph Boscovitch, who first published it in an important treatise printed in Vienna in 1759.

Both of these early philosophers based their theories upon such unsatisfactory experiments as they were able to observe before scientific methods had begun to exhibit the exactness and the delicacy now characterizing them.

It seems equally remarkable that their deductions should accord so perfectly with later determinations, and that so little progress should have been made since, in researches upon inter-molecular relations.

That portion of the theory of Boscovitch which supposes several alternations of attractive and repellant resultant forces, has received some apparent confirmation by experiment, but it is by no means proven. It would seem more probable that the attraction of cohesion, and the repulsive force of heat energy, are the two simple inter-molecular forces which determine intermolecular distances.

Rankine's theory of molecular vortices affords a hint as to the possible action of heat here referred to.

4. It would seem very possible that phenomena apparently conflicting with this latter belief, will find explanation in molecular changes of position, rather than in the interaction of forces differing in nature, from those familiar to us.

In all familiar examples of solids the force of repulsion increases more rapidly than that of attraction, as the molecules are forced to approach each other, and the reverse is observed as they separate. The molecules occupy, when undisturbed by external forces, positions of equilibrium which have been attained by passing over a range through which, at a constant temperature, attractive force has predominated, and the alternations referred to above, can, if observed at all, only be seen after compressing the mass and forcing the particles past this first position of equilibrium.

The other principles stated, if not absolutely proven by experiment, are at least rendered extremely probable, and are uncontradicted by any recorded phenomena.

Hooke's law has been proven sufficiently exact by numerous experimenters upon the tensile and compressible resistances of materials, and by Chevandier and Wertheim, and later, more fully, but not with more precision, by the writer, in a series of experiments upon torsional resistances, in which the apparatus was made self-registering.*

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* Journal Franklin Institute, April, 1873.

5. We remain at present in almost perfect ignorance of the true nature and exact relations of the forces which are concerned in determining these physical conditions of matter.

So much as is known is, apparently, in conflict with every hypothesis yet proposed, in some essential point, yet we cannot resist the conviction that these forces are simple modifications of those most familiar to us; the attractive force being that of cohesion, and the repellant force being that of heat motion, while a third force, or third component of the one force, is that known as "polarity."

It would seem, from the experiments of Coulomb, Professor Henry, Plateau and others, that the elasticity and resistance of solids are due, principally, to the action of molecular forces during changes of molecular grouping, rather than to changes of distances between particles. The latter has an exceedingly slight range, but, as shown by those experiments of Wertheim, which indicate an alteration of volume by tensile stress, an actual, though slight, change of atomic distances does probably take place.

It cannot be asserted that these experiments are absolutely conclusive on this point.

6. The experiments of Professor Baden Powell upon the effect of heat in altering the breadth and diameter of Newton's rings,* are strongly confirmatory of the opinion, already expressed, that the repulsive force of the intermolecular spaces is that of heat motion.

7. The experiments of Dr. Andrews upon the "critical state" of substances passing from the liquid to the gaseous condition, and *vice versa,* are considered, by him, to indicate that those states are "but widely separated forms of the same conditions of matter," and that the one may be made to pass into the other without abrupt change.†

M. Cagniard de la Tour made the earliest experiments in this field in 1822, and was closely followed by Faraday.

Dr. Andrews' more recent researches are probably the most complete and the most fruitful. His investigations of the phenomena accompanying the changes of carbonic acid, as to temperature and pressure, and, particularly, while passing through that phase of transition known as the "critical state," have thrown some light upon molecular relations.

The "critical state" is that condition of matter in which it exists when just passing from the liquid to the gaseous state, or the reverse, by a regular, as distinguished from the more familiar, irregular process. It constitutes the "debatable ground" between these two states of matter, whence it is impossible to determine in which condition it should properly be considered.

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† Phil. Trans., 1834.

† Phil. Trans., 1869.

It is found that, when just approaching this point, liquids are even more compressible than in the antecedent gaseous condition.

Water passes through the critical state at a temperature estimated at about 770° Fahr. by M. Cagniard de la Tour, and at a pressure too high to be accurately measurable.

At this high temperature and pressure it dissolved the glass tubes in which it was attempted to confine it.

8. Dr. Andrews found that carbonic acid exhibited this gradual and regular change from the gaseous to the liquid condition at a much lower temperature.

The experiments of M. Tresca on the "flow of solids"* are exceedingly interesting and valuable in this connection, as lending confirmation to the views expressed by Dr. Andrews.

The phenomena of the critical state are considered by high authorities as strongly confirmatory of that portion of the Boscovitch theory which most requires confirmation.

9. After having passed from the gaseous to the liquid state, matter is found exceedingly difficult to reduce in volume. A pressure of one atmosphere produces, in the case of water, a decrease of volume of but *forty-six one millionths.*†

10. In liquids, attractive force makes itself observable, although the extreme mobility of their particles prevents the ready or accurate measurement of its value.

Professor Henry, who made the first attempt to estimate it, considers that the cohesive force of water is several hundred pounds per square inch. This considerable force resists change of distance between molecules, but does not perceptibly influence change of form, and we have, therefore, the curious fact to observe, here, of the coexistence of high cohesive force with almost perfect mobility of particles; the latter condition rendering the resistance to change of form very difficult of detection and measurement.

11. In the process of transition from the liquid to the solid state, in addition to the generally continued diminution of volume, molecular approximation, and the assumption of new positions of equilib-

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* London *Engineering*, 1866–67.

† John Canton, Trans. Royal Soc., 1762.

rium by the particles, in consequence of the abstraction of heat, another, as yet unexplained, action occurs, which may be called, for want of a better term, *molecular polarization.*

This new force comes into play at a point which is definitely fixed, for each substance, on the scale of temperature, and although the resistance to forces tending to produce changes of intermolecular distances may be but little increased, resistance to change of form makes itself observable, generally suddenly, and solidification is produced by the fixation of molecules in definite relative positions.

The characteristic which distinguishes the solid from the liquid state is the effect, apparently, of this force of "*polarity*," simply.

Dr. Henry remarks "It is in accordance with the phenomena of cohesion to suppose that when a solid is liquefied by increase of temperature, instead of the attraction of the liquids being neutralized by the heat, that the effect of this agent is merely to neutralize the polarity of the molecules, so as to give them perfect freedom of motion around every imaginable axis." This author was probably the earliest to detect, and to state thus precisely, the part played by this force of polarity in molecular phenomena.

12. The cohesive force which makes its appearance when a gas becomes liquified is probably considerably increased in all cases when solidification occurs; but the mobility characteristic of the liquid state is so perfect that it is difficult to make the comparison, and we, consequently, have scarcely any reliable data from which to estimate the value of cohesion in fluids. The most valuable are probably those of Prof. Henry,* already referred to, from which he estimated the cohesion of water to be nearly that of ice.

13. In the cases of some, and, probably, of many solids, the relation of these intermolecular forces becomes such that, if the force of polarity is overcome, and the molecules forced from the relative positions which they originally assumed, without, at the same time, changing their relative distances to such an extent as to destroy their tenacity, they may slide into new positions in which they will tend, under the action of this polarity, to remain permanently as before. The action here referred to is illustrated by some of Coulomb's experiments on torsion, by those of the writer on the same point, by M. Tresca's experiments on the flow of solids, and by the common methods of "squirting" lead pipe and of "spinning" brass.

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* Proceedings Am. Phil. Soc., 1844.

In the experiments of Coulomb, a wire which had been twisted so far as to have taken a permanent set, was found to have its elasticity still unimpaired, and could be twisted as far, without taking a new set, as it could originally before taking the first. In some examples, several successive positions of set, with equal elastic limits, were found. Even a thread of clay, soft and plastic as it is, exhibits this peculiar action. The experiments of the writer on iron and steel $\frac{5}{8}$ of an inch in diameter give precisely similar results.

These experiments are usually quoted in support of the Boscovitch theory of alternation of attraction and repulsion, but it may certainly be questioned whether the view just presented is not by far the more probable one—the successive sets being produced by successive renewals of the action of polarity, as the molecules were forced to move among each other without such increase of intermolecular distances as to destroy their cohesion.

14. In cases of true crystallization we have no means of determining whether the formation of the crystal, in its invariable and symmetrical form, is due to Prof. Henry's polarizing force, or to still another distinct force, or component of the one intermolecular action.

Since, however, it would be generally supposed that one force may produce both phases of polarization, the universally recognized "principle of least action" in nature suggests the belief that there is but one.

The phenomena of magnetism, and of diamagnetism, are undoubtedly exhibitions of molecular action, under these intermolecular forces, but it remains to be determined whether they are, also, produced by the force under consideration.

The experiments of MM. Chedeville and Treve, at Brest, and of other experimenters, indicate, at least, some relationship between, if not the identity of, these forces.

15. It is sufficiently evident that, granting the relation of these several forces to be such as is indicated by what has preceded, the attractive, repulsive and polarizing forces of matter may have any relation of intensity, and, consequently, that substances may exist in very various conditions.

We may have a mass of matter, in which repulsion, of any degree of intensity, may be recognized only, as with the gases; attraction and repulsion may equilibrate each other, uniting to produce a mass resisting change of molecular distance, with any degree of force, and yet, in the absence of polarity, offering little or no resistance to change of form, as is the case with the mobide liquids. The addition of the polarizing force confers viscosity upon liquids, and this viscosity has every value until, as it becomes great, in proportion to the intensity of the other forces, we find the mass rigid, and, if cohesion is, at the same time, considerable, the body is hard. A body like the diamond would have great cohesion, and, relatively, still greater polarity; iron exhibits great cohesion and considerable polarity, at ordinary temperatures, polarity vanishing faster than cohesion, probably, when the metal is heated.

16. There are some remarkable, and still mysterious, molecular phenomena for which we have neither the space nor the data necessary for their discussion.

The most striking is what may be termed molecular friction. This peculiar phenomenon has been frequently noted, but does not appear to have attracted the attention or to have provoked the careful research that its possible importance should have prompted.

If a bar of steel is magnetized and demagnetized, it is noticed that it most readily accepts afterward the polarity first conferred upon it. What is known as "residual magnetism" is another method, probably, of manifestation of the same action. It is well settled that magnetic phenomena are phenomena of, or invariably accompanied by, molecular movement, and there appears, in these cases, to be exhibited a kind of interatomic friction which, producing a "set," prevents the return of the particles to their original positions, and allows the force of polarity to be most readily overcome in a definite direction.

The "fatigue" of metals, which has been so fully and elegantly investigated by Wohler,* may be an exhibition of the effect of similar causes. It may, however, be simply due to unequal tension, and the consequent gradual rupture, successively, of overstrained portions of metal, the work being thus thrown upon smaller and smaller sections of sound metal, until the whole becomes finally disrupted.

The determination of the effects of chemical changes upon molecular tensions presents a wide and, as yet, almost absolutely unknown field of research.

For one of the most complete and consistent theories of molecular physics which has been proposed, we are indebted to Prof. W. A. Norton.†

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* *Uber die Festigkeitsversuche mit Eisen und Stahl:* A. Wohler, Berlin, 1870.

†American Journal Science and Arts, 1872.

17. It will require much additional experimental investigation, and far more carefully planned and systematic research than has been yet given to the subject, to furnish the basis for a perfectly satisfactory theory of the nature and modes of action of corpuscular forces.

If we may draw any conclusions from what is known already, we should probably infer that, when in the gaseous condition, the molecules of matter tend continually to separate, under the action of a repellant molecular force, which has greater magnitude as the gas is compressed.

As this compression goes on, either by the application of mechanical force, or by the abstraction of heat, a point is finally reached at which an equilibrium occurs between the forces tending to produce a reduction of volume and those tending to expand the mass.

Any effort which may be made to destroy this equilibrium, and to increase the intermolecular distances, and, by the same action, to enlarge the volume, may be found, as in the case of water, to be resisted with some force, while an effort to produce a change of distance, by forcing the particles from their positions of equilibrium in the other direction, reducing the volume, may meet very great resistance. And while resistance to change of distance is observed, it may happen that the resistance to change of position, among the molecules in a group may be, and often is, quite unobservable.

18. Abstracting heat still further, solidification finally occurs.

As, throughout the process of contraction, up to this point, the attractive force has gradually increased, in its power of resisting disturbance of equilibrium and change of molecular distances, it would be anticipated that the solid would exhibit greater cohesion than the liquid. There is but little evidence bearing upon this point, and it will require extended and skillful, as well as patient, investigation, in the field of Prof. Henry's labors, to furnish what is needed. What we have learned indicates that this increase does occur, and that its amount is very great.

19. The simple increase of cohesive force, where the distances between the molecules are still so immense in comparison with the magnitudes of those molecules, would not be expected to give increased elasticity of volume. On the contrary, during the change from the gaseous state the loss of elasticity of volume has been a marked characteristic.

(It is considered by some philosophers to be well ascertained that the radius of a molecular action is less than one five-millionth of an inch in some cases,* and that it probably does not equal one two-thousandth of an inch in any in instance.† At least one writer considers that the molecule has an orbital radius not exceeding one two-thousand five hundred millionths of an inch.‡ The existence of animal organisms as small as one two hundred and fifty millionths of an inch in length indicate that even these figures are not probably too small.)

20. An unavoidable inference from the language of authorities most frequently quoted is, that elasticity of form—the quality of which the so-called elasticity and the resilience of solids is a consequence—results from the existence of a property in solid matter by which change of distance between molecules may occur to a marked extent without rupture.

This, if true, would indicate elasticity of form to vary with elasticity of volume.

This, we should infer, may be a mistake, the elasticity of volume being probably less in the solid than in the liquid, while elasticity of form is absent in the latter.

If it be the fact that the elasticity of form, and the resilience of solids are not due to elasticity of volume, primarily, we are justified in attributing them to the property of pliability, produced by the comparatively wide range of intermolecular movement permitted by the force of polarity. In examples of great elasticity, it may have an intensity, small in comparison with that of the other forces acting in the mass, and, at the same time, it, or the cohesive force, or both, may vary at a less than ordinary rate with a given change of distance.

21. We have followed what can be considered as scarcely more than a train of hypotheses, but it is evident that the faint light which has been thrown upon the subject exhibits, at least, a probability that they approximate with some degree of closeness to the truth.

We may deduce from what has been stated, finally, that it is extremely probable that the contraction in volume, of a solid, by approximation of molecules, will increase the absolute strength, while decreasing the viscosity of the body, and, as a consequence, diminishing the resilience, by contracting the elastic limits. The mass might have a higher modulus of elasticity, and higher tenacity, but would more readily yield under a shock or a blow.

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* Wartman.

† Robison.

‡ Gaudin.

22. We should expect these changes in metals to be most marked within ordinary limits of temperature, in the cases of those metals which have lowest temperatures of solidification, since, in such examples, the complete change from absolute mobility to perfect rigidity is comprised within the least range of temperature.

23. All other things being equal, since lowering the temperature reduces the mobility of particles, and increases the viscosity of the metal, we should anticipate that the greater toughness of the material at the higher temperature, while in the solid state, would not only exhibit itself in a greater resilience, but would also modify the character of the fracture, when ruptured by external force, making it less "short" and glass-like—wherever the substance possessed any thing of the characteristics illustrated by Coulomb's experiments, noted above—at a high, than at a low heat. The fracture would be expected to appear "fibrous" and "thready" when, as in ordinary wrought iron, foreign substances present or varying quality of metal should produce in adjacent parts unequal "drawing down" at the higher temperature.

24. Where, as in iron, the change from the liquid condition through the pasty, semi-fluid welding state, to the condition of comparative brittleness at ordinary temperatures, has been a somewhat regular one, it would be anticipated that the change might continue with still further decline in temperature. It would not appear unlikely that such change might progress indefinitely, or until resilience was absolutely destroyed by the approximation of molecules, and the coincident fixity due to a maximum intensity of polarity.

Where the body has sensible viscosity and considerable resilience it would be expected that, if broken suddenly, as by a quick jerk its fracture would be complete before the particles, retarded by inertia and by molecular friction, could have time to shift their positions, while, when slowly broken, a considerable amount of motion might occur before rupture could be completed.

In the former case, the appearance of the break and the diminution of section would be characteristic of tough, and in the latter, they would apparently indicate brittle, material.

25. Such being, not improbably a statement of the general effects of changes of temperature upon matter, it remains for the engineer to determine, by experiment, how fully the most generally useful metal, iron, presents an example of these effects, and how far they are modified by differences of chemical constitution and of physical

The most interesting and instructive experiments which have yet been made are those of Fairbairn, Kirkaldy, Professor Johnson, of a committee of the Franklin Institute; of a committee appointed by the King of Sweden, of Brockbank, Joule, Sandberg and Spence.

26. Tredgold, the celebrated engineer, whose intelligence and experience have given his published opinions very great weight, believed that any increase of temperature would diminish the tenacity of metals.

Dr. John Percy, on the contrary, with probably the majority of engineers, believe the opposite to be the effect, basing the belief upon the well-known fact that accidents more frequently occur from fracture in cold than in warm weather. So common is this belief, that the statement recently made, that the real effect of decrease of temperature, other things being equal, may be to increase tenacity, has been received with very general distrust.

27. The magnitude of a change of tenacity arising from simple approximation of molecules, and consequent increase of cohesion, could not be expected to be very great, since this change of distance between adjacent particles is but about seven one millionths of its ordinary value for a range of one degree. Were the tenacity to vary as the square of the distance, the consequent variation would be but one and a half per cent., and would be but two per cent. were it to vary, within this range, as the cube of the intermolecular distances for a range of one thousand degrees.

28. In comparing the conclusions deduced by the several experimenters, of whose labors the following is an abstract, some evident misconceptions will be noted, which plainly arise from the very common error of attempting to estimate the strength of materials from experiments in which they are tested by shock, forgetting that a material may be immensely strong, and yet, if brittle, non-resilient, may be readily broken by a blow which would leave uninjured a less tenacious, but more ductile, specimen.

It has evidently been quite unsuspected, by the majority of experimenters, and of writers on this subject, that change of temperature may, while producing an alteration of the cohesion of metals, effect a directly opposite change in its ductility, and that, consequently, the substance may exhibit greater tenacity, and may, therefore, better resist a steady strain, while at the same time its ductility may be so greatly decreased by the same cause as to greatly lessen its resilience, and thus, though stronger, it may be less capable of resisting shocks.

29. A committee of the Franklin Institute, of the State of Pennsylvania, consisting of Professor W. R. Johnson, Benjamin Reeves, and Professor A. D. Bache, were engaged, during a period extending from April, 1832, to January, 1837, in experiments upon the tenacity of iron and of copper, under the varying conditions of ordinary use.

The effect of change of temperature upon those metals was investigated with equal intelligence and thoroughness, and most valuable results were obtained.

30. Upward of one hundred experiments upon copper, at temperatures ranging from the freezing point up to 1000° Fahrenheit, exhibited plainly the fact that a gradual diminution of strength occurs with increase of temperature, and *vice versa*, and that the change is as uniform as the unavoidable irregularities in the structure of the method would allow.

The law of this variation of tenacity, within the limits between which the experiments were made, was found to be closely represented by the formula,

$$D^2 = C\,T^3,$$

i. e., the squares of the diminutions of tenacity vary as the cubes of the observed temperatures measured from the freezing point.

31. The committee, in the course of their exceedingly judicious and complete series of deductions, say:*

"The temperature of no tenacity is generally supposed to be that at which the fusing point of the given substance is placed, and the point of maximum tenacity ought upon general principles to be found at the point at which least heat prevails, that is, at the natural zero, or point of absolute cold, if such a point exists in nature.

"Between these two extremes, it might be supposed that the tenacities of different substances, particularly such as are capable of passing immediately from the solid to the liquid state, would be found to obey certain laws.

"As the total cohesion, at the maximum, would present, to a mechanical agent tending to overcome it, the whole of its resistance, and as, at more elevated temperatures, a part of that tenacity would be overcome by heat, and the rest would be destroyed by the mechanical force, it is evidently a question of experiment to decide what relation the two forces have to each other, at the temperatures between the two extremes to which we have just alluded.

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* Report of Committee, p. 74. Philadelphia: Merrihew & Gunn. 1837.

"To decide the theoretical question, or, in other words, to deduce from the experiments a law which might be expressed in an abstract form, corresponding to all the possible phenomena, would require a state of the materials different from that usually found in commerce or employed in the arts.

"It would also, as we have seen, require a knowledge of that about which philosophers, no less than practical men, are far from being agreed, namely, the point of absolute cold."

32. The committee do not fail to observe that there are indications that the curve, of which their formula is an approximate equation, has, very probably, a point of contrary flexure at a temperature somewhat below the highest at which they were able to experiment, or near the point at which one-half the tenacity of the material is destroyed.

This inflection of the curve, which indicates that no parabolic formula can be made to represent, accurately, the change of tenacity with varying temperature, is very clearly exhibited in the curve laid down from the experiments on the strength of *wrought iron*, which were next made by the committee.

33. These experiments were 73 in number, at temperatures between 212° and 1317° Fahr., and comparisons were made with the strength of the same bars at ordinary temperatures, as determined by 163 experiments.

The bars were generally broken at sections reduced by the file, and the results give but little indication of the effect of change of temperature upon the resilience and extensibility of the metal; but they afford most interesting, accurate and valuable measures of the effect of heat upon tenacity.

34. It was this investigation which first disclosed the remarkable anomaly of the existence of a point in the scale of temperatures, usually, if not invariably, considerably above that of ordinary temperature, at which the metal exhibits a maximum of tenacity.

34. By heating a number of bars to 572° F., which was found to be very nearly the average temperature of maximum strength, and breaking them at that temperature, it was found that a mean of experiments, on the best qualities of rolled iron, gave this maximum as 15·17 per cent. higher than the tenacity of the same samples at ordinary temperatures.*

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* Report of Committee, p. 213.

The irregularity of structure of specimens tested was found to cause an irregular variation of strength amounting to 10 per cent.

35. Taking 80° Fahr. as a standard temperature, the committee discovered that the fifth power of the diminution of tenacity from the maximum, determined as just stated, varied as the thirteenth power of the temperature above 80° Fahr.,* or

$$D^5 = C\,(T - 80°)^{13},$$

where D = diminution of tenacity, T = temperature, C = a constant.

At the temperature of about 400° and 1200°, points of departure from the curve took place as already stated, the deviation from the law expressed by the formula becoming quite marked.

35. The committee made a series of experiments upon the effect of annealing in altering the tenacity of the metal.

They found no measurable change in specific gravity, except with specimens which had been hammer-hardened. The tenacity was diminished to an extent which follows very closely the order of temperature at which annealing was performed, and this loss varied from $2\frac{1}{2}$ per cent., when annealing was performed at low temperature, to 46 per cent., when the metal was annealed from a bright welding heat.

The result seems quite variable, but, at about 1100°, the losses had a mean value of about 15 per cent., while, at a welding heat, they averaged nearly 25 per cent.

In testing old boiler plate, a loss was supposed to have been proven, which was attributed to this cause, and which amounted to about 6 per cent.

Unfortunately, the experiments of the committee do not afford the data requisite for determining the resilience of these specimens, and we are unable to learn whether the observed depreciation of strength was accompanied, as we should expect, by an increase of ductility.

36. No experiments were made at temperatures less than 32°, and it remained for further research to determine the behavior of iron at exceptionally low temperatures. The work of the committee was most skillfully performed, and most conscientiously recorded and reported. Together with the equally exhaustive and thorough work of the full committee on steam boiler explosions, of which this was a part, it

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* Report of Committee, p. 218.

affords most valuable and reliable additions to our experimental knowledge.

These were the first experiments ever made on an extended scale, and the determination of the area of fractured section, the measurement of elasticity, of latent heat, specific heat, the conducting power, and other properties of iron and copper, were made with much greater care than could have been expected at that early period. The committee were engaged in the work nearly five years, and the expenses incurred were defrayed by the United States Treasury Department.

37. A somewhat similar series of experiments were made by Sir Wm. Fairbairn upon rolled iron,* and the same behavior was noted, under varying temperatures, as was so well shown by the earlier researches of the committee of the Franklin Institute.

The tenacity of Staffordshire boiler plate was examined at temperatures varying from °0 Fahr. to a dull red heat—probably 1000° Fahr.

This iron is not of high quality, and some marked deviations were observed from the general direction of alteration of strength.

The tenacity of the specimens gradually increased, as the temperatures rose from 60° to 395° F., and thence diminished, until, at a red heat, the strength became reduced to the extent of 25 per cent.

The tenacity recorded at 0° F. was, however, 6 per cent. greater than the *mean* noted at any other observed higher temperatures, but not greater than that of individual specimens.

38. Other experiments were made upon rivet iron, which was necessarily of better quality than the Staffordshire plate.

The tabular statement of the results shows a gradual and quite regular increase of tenacity from 60° to 325° F., the strength being given at 68,816 and 84,046 pounds per square inch at those points respectively—a difference of 30 per cent. The tenacity then diminished as temperature rose, becoming reduced to 35,000 pounds per square inch at a red heat.

The strength of 30° F. was slightly greater than at ordinary temperatures, the figure given being 63,238 pounds per square inch.

39. Experimeuts made by Fairbairn on the effect of temperature upon cast iron give less uniform, but still instructive, results.†

With No. 3 iron very unsatisfactory and contradictory results were obtained, in consequence of the irregular character of its structure and chemical constitutions.

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* British Association Report, 1856.

† British Association Report, vol. 6, 1837.

Coed-Talon iron No. 2 exhibited continual decrease of transverse strength as the temperatures increased. Both cold and hot blast irons were experimented upon, at temperatures ranging from 26° to 190° Fahr. with the following results:

Cold blast, at 26° and 190°, decreased in strength in the proportion of 874 to 743. Hot blast, at 21° and at 190°, decreased in strength in the ratio of 811 to 731.

It should be remarked that these experiments were made in the early days of hot blast, when the differences in the character of hot and of cold blast iron were more marked than at a later date, when the management of the former had become generally, and more perfectly understood.

40. Mr. Fairbairn remarks:* "On the whole, we may infer that cast-iron, of average quality, loses strength, when heated beyond a mean temperature of 120°, and that it becomes insecure at the freezing point, or under 32° Fahr."

He supposed that the fact that, in some experiments, he found No. 3 iron to increase in strength with rising temperature, is due to its great "irregularity and rigidity."

He also remarks† that "The infusion of heat into a metallic substance may render it more ductile and probably less rigid in its nature, and I apprehend it will be found weaker and less secure under the effects of a heavy strain."

41. The experiments of Roebling, referred to in his report to the officers of the Niagara Falls Suspension Bridge Co., in 1860, do not throw much light upon the question under consideration.

Mr. Roebling's remark that metal, of as good quality as that upon which he experimented, would be "safe at the North pole,"‡ may justify the inference that he supposed that such iron would at least not lose tenacity when very cold.

(To be continued.)

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* On the Application of Cast and Wrought Iron to Building Purposes: London, 1844, p. 66.

† Journal Franklin Institute, 1840, vol. 25, p. 58.

‡ Journal Franklin Institute, 1860, vol. 40, p. 361.

NICKEL AND ITS USES IN THE ARTS, COINAGE AND NICKEL PLATING.

By Dr. Lewis Feuchtwanger.

(Continued from page 140.)

During the suspension of specie payment in 1837 in the United States, the writer conceived the idea of proposing to the Government the issue of a German silver cent, and, as an experiment, he issued 1½ millions of such tokens under his own name, with the permission of the Secretary of the Treasury, for the purpose of obtaining popular favor to this metallic currency. His petition to Congress of that year, which was presented to the United States Senate by Mr. Benton, and to the House of Representatives by John Quincy Adams, with highly flattering encomiums, was referred to the United States mint for report; this report was unfavorable, the director giving some very frivolous reasons, as received from the chemist; but the same individual, while smelter of the mint, took, twenty years later, the opportunity of recommending a nickel compound as a one-cent currency, which, however, did not find much favor in the country, as the coin was not white, and became dirty yellow when in circulation for a month. But 12 per cent. nickel was used in the composition, not by any means sufficient to whiten the copper, while the writer's token, now of thirty-six years' standing, looks at present more like sterling silver than the best American coin. All the numismatic works of this and other countries have adjudged to the writer the palm for his ingenious improvement in the currency.

The nickel coinage.—After the introduction into the United States of the *one cent* coin, which really was a failure, the Belgian and Swiss Governments passed laws in 1860 for issuing a nickel currency—the first to the amount of four millions of dollars, of the denominations of 20 centimes (4 cents), of 10 centimes (2 cents), and 5 centimes (1 cent); while Switzerland issued a German silver coin of similar denominations to the amount of one million of dollars. The United States had coined one million of dollars in the one cent coin already in circulation. The United States Congress wss induced, in 1867, to pass a law for issuing a five cent nickel coin, to consist of 25 per cent. nickel and 75 per cent. copper in place of 12 per cent. nickel and 88 copper. This latter redeemed its honor, for the coin looks really fine, and the late law passed will give in future a respectable small nickel currency of one, three, five and ten cents, of the following weight:

1 cent	to weigh	20 grains.
3 "	"	30 "
5 "	"	50 "
10 "	"	100 "

Instead of five millions of dollars in value of the other nickel currency in circulation in 1868, there will be twenty million dollars of the value of the present nickel coinage in the United States.

The annual production of metallic nickel in the world has been estimated by Mr. Wharton as follows:

England produces	700,000 lbs.
Germany "	500,000 "
Sweden "	50,000 "
United States produces	50,000 "

Which is but 1,300,000 lbs., of which the coinage of the mints in Belgium, Switzerland and the United States absorbs at least 200,000 lbs. per annum, and not less than 1,000,000 lbs. is used for the manufacture of German silver ware, which would leave 100,000 lbs. for the new branch of industry—the nickel plating. The German silver which has been worked for the last thirty years into spoons, forks, tea sets, and many innumerable articles, many of which are plated over with silver, must be of the value of from forty to fifty millions, derived from nickel. This metal forms the basis for a future important revenue in this country, for, with the increased consumption of nickel either as coin, German silver, or plated nickel ware, we diminish the quantity of silver in that channel, and leave the surplus to come back into the general circulation.

Nickel Plating.—An important branch of industry has been in practice in the United States for the last few years only, although it was recommended by Alfred Smee, in his "Elements of Electro-Metallurgy," in 1852, who, in page 193, speaks of nickel in the following words:

"Nickel is the last in the list of noble metals, being the most ignoble of that class. The nitrate and sulphate of nickel, the ammonio-nitrate and sulphate of nickel, the nickelo-cyanide of potassium, but especially the chloride of nickel, require consideration. The nitrate of nickel is very soluble, but the metal has no great inclination to be precipitated, for the hydrogen appears rather to prefer being evolved than to reduce the metal. The sulphate of nickel is also used as a double salt, and the metal is reduced more readily from it than from the nitrate. It is best reduced by the compound battery process with a platinum positive pole, though a nickel positive pole may be employed. The solution of either nitrate or sulphate combined with alkalies, those of ammonia deserving the preference, ought to be as strong as possible. The chloride of nickel forms an excellent material for precipitation, by means of a nickel positive pole with one or two batteries. The nickel so deposited has a peculiar white, brilliant lustre, looking almost like glass. This deposit is so beautiful, when removed from the negative pole, that it forms a great contrast to the common nickel metal, and no person would ever suppose that there was any similarity of composition between that substance, still less identity. For practical purposes the chloride is first, and next to it is the sulphate for the regaline deposit."

It has been ascertained that the nickel-plated ware lasts four times as long as the silver-plated, and is four times cheaper than silver-plating, nor does it tarnish as easily as silver; for sulphuretted hydrogen acts readily on silver, and not on nickel. We see now everywhere the utensils for the house, ship, harness and carriage trimmings, dental, surgical, philosophical and musical instruments, reflectors, sadirons, stair-rods, guns and pistols, many models requiring protection from the oxidizing or corroding action of the air or water, with a vast number of articles in daily use, as also the polished iron and brass materials used on board of a ship, where the salt water atmosphere is so liable to corrode, and machinery of every description plated with nickel. There was a capstan so plated, at the late fair of the American Institute, which the writer conceived to be injudicious, for the reason that nickel is magnetic, and should not be employed near the compass. The batteries used in the nickel-plating are of various inventors, such as the Wollaston, Daniell, Grove, Bunson and Smee batteries.

Daniell's battery consists of a box of eight inches to two feet in height and four inches in diameter. The outer vessel is to be made of copper, of which the external part may be painted, as it plays no part in generating electricity, while the inner remains uncoated. Into this cylinder a solution of sulphate of copper is to be poured, instead of the dilute acid used in other batteries. In order to separate the zinc cylinder from the sulphate of copper, it rests in a porous cup, which contains the zinc surrounded by dilute sulphuric acid. As soon as contact is made the zinc is dissolved, and sulphate of zinc is retained in the inner part of the vessel; whilst, instead of the hydrogen being evolved at the negative metal, it reduces the copper from the sulphate of copper. The more porous the inner vessel is, the greater is the quantity of electricity developed; therefore coarse canvas or porous earthen tubes are now employed instead of the bladder. Daniell used for his positive metal cast zinc rods, which he amalgamated. But zinc cylinders are indispensable, and the porous vessel must not touch the battery plates. This battery has the power of generating exactly the same amount of electricity for a long time, and is celebrated for its effects.

Grove's battery employs platinum as the negative metal, and has in the inner porous cells strong nitric acid, while the outer cell of the zinc cylinder contains dilute sulphuric or muriatic acid; the nitric acid, when employed, is decomposed by the hydrogen, and deutoxide of nitrogen is evolved, which is converted into nitrous acid when coming into contact with atmospheric air.

This battery is remarkable for its intensity. Four such single batteries are sufficient for large operations in electroplating. The only drawback to its general uses is the nitrous acid fumes, which are very offensive; the same fumes also attack the zinc to a considerable extent. While Daniell's battery has its good side, it has also the disadvantage of varying the quantity of electricity by altering the wires as to size and length, as also the labor to set a Daniell's battery in motion; also the trouble and expense in using the porous tubes, and the necessity of continually reamalgamating the plates, and, lastly, the small quantity of fluid which the porous pots contain to dissolve the sulphate of zinc.

In Grove's battery the nitrous acid fumes of the nitric acid battery which are so objectionable have been changed in the application of bichromate of potash, which, in a concentrated state of solution, is put on the negative side of the battery, while dilute sulphuric acid is used on the zinc sides. This latter is dissolved on the outer side of the battery by dilute sulphuric acid, and the bichromate is decomposed at the negative end.

Smee's Chemico-Mechanical Battery.—This battery is the same as Daniell's, but sulphate of copper is replaced by platinum. A small quantity of nitro-muriate is thrown down on the sheet-platinum, previously roughed by sand-paper. The same process may be performed on palladium, silver (roughened by nitric acid), plated copper, iron of every sort, and on charcoal—all with the same good result.

Silver is most generally employed on account of its cheapness, and not undergoing any alteration. The object is to afford a surface to which the hydrogen shall not adhere, but shall be evolved from it. The platinized silver used for this purpose ought to be thick enough to carry the current of electricity, and should be roughened either by sand-paper or by brushing it over with a little strong nitric acid, so that a frosted appearance is obtained. The silver is then washed and placed in a vessel with dilute sulphuric acid, to which a few drops of nitromuriate of platinum are added; a porous cup is then placed in this vessel, with a few drops of diluted sulphuric acid; into this the zinc is put. Contact being made, the platinum will in a few seconds be thrown down upon the surface of the silver, as a black metallic powder. The operation is now completed and the platinized metal ready for use.

Iron, if prepared in the same manner as silver, may be used for the same purpose, and employed with advantage; all that is required is to rub a little nitromuriate of platinum over it and an immediate deposit of the black powder takes place. The liquid generally adopted to excite this battery is a mixture of 1 part by measure of sulphuric acid and 7 of water, which will be found amply strong for all purposes. Where we desire greater intensity, it can be obtained by the addition of a few drops of nitric acid, but if too much be used, it might attack the silver. The operator will frequently find it advisable to use diluted sulphuric acid, only retaining 1-10th to 1-16th of the pure acid, and adding some acid when the first is exhausted. The zinc, acid and water being severally required to excite the battery, they may be regulated so that they should all be exhausted at once, so that the zinc should neutralize the acid and the resulting sulphate of zinc exactly saturate the water.

In place of platinized silver, the carbon plates, also the chromium plates have been used with decided success for the negative poles.

From what has been stated, it is obvious that Daniell's battery is distinguished for its constancy, Grove's for its intensity, and Smee's for cheapness and simplicity in the development of electricity. It is of great importance to know which battery yields the greatest amount of galvanic fluid at the smallest cost, least labor and greatest convenience. The main tendency of the three described batteries lies in the action of zinc upon water, and when, in connection with acid, to form sulphate of zinc.

Bunsen's battery depends upon the application of carbon cylinders and forms also a convenient and economical apparatus.

The platinized silver plates of Smee's battery are now replaced by carbon plates, as also by chrome plates which are said to form a very constant battery; while offering a greater surface for the decomposition of the metallic salt, they must prove more economical.

Coating with Nickel.—Napier, in his Manual of Electro-Metallurgy, speaks of nickel coating; that it is very easily deposited and may be prepared for this purpose by dissolving it in nitric acid, then adding cyanide of potassium to precipitate the metal, after which the precipitate is washed and dissolved by the addition of more cyanide of potassium. The cyanide of potash has proved unsuitable for nickel plating; he says that he coated articles with nickel in 1847, and up to 1853 they still retained their brilliancy and continued untarnished. Napier gives also the following practical instruction for plating, in the following words: It is indispensable that the battery should be so arranged that the quantity of electricity generated should correspond with the surface of the articles to be coated, and that the intensity should bear reference to the state of the solution, that is to say, that the quantity should be sufficient to give the required coating of metal in a given time, and the intensity such as to cause the electricity to pass through the solution to the articles. It is also essential that the plates of metal forming the positive pole with the solution should be of corresponding surface to the articles to be coated, and face them on both sides. A rough idea may be given here of a plating vessel which is about 6½ feet in length by 33 inches in breadth and 33 inches in depth, and contains from 200 to 250 gallons of solution; the silver or nickel plates serving as electrodes. Two battery troughs are arranged so as two consist of six batteries of three pair intensity. The zinc plates, immersed in the acid from which electricity is disengaged and the electrode exposed to the articles receiving the deposit, being in proportion.

The vat should contain the solution with the battery having the zinc pole inverted, connecting with rods upon which the articles are to be suspended with wires, and a copper pole is then connected with the electrode. So soon as the articles which are connected with the negative pole of the battery and the electrode connected with the positive pole are immersed in the solution, the galvanic circuit is completed.

To ascertain the amount of metal deposited, it is well to weigh such articles carefully before and after the operation is completed.

Description of an extensive establishment of nickel plating in actual operation for saddlery hardware, sadirons, bits and turrets, and where 500 lbs. material are daily plated, finished and brought to market:

1. It consists of a lage wooden box, which is five feet six inches long, fourteen inches deep, and two feet wide, lined with asphaltum varnish so as to be perfectly tight.

2. The capacity of the box is seventy gallons liquid, consisting of hot water, in which three-quarters of a pound of the double salt of sulphate of nickel and ammonia to each gallon are dissolved.

This vat is connected by wires with (3) a *Smee battery*, consisting of six zinc plates, 9 × 10 inches, which are previously well amalgamated with mercury, (4) and six carbon plates, likewise 9 × 10 inches. This box may be lined with lead and must contain ten gallons of water, to which twenty ounces of oil of vitriol are to be added. The carbon plates are now put between each zinc plate, and will keep up the evolution of hydrogen gas as soon as put in connection; it will remain in active operation for two weeks, while the zinc plates need no re-amalgamation for four months.

5. Copper or brass wire is stretched across the decomposing or plating vat, for suspending the various articles to be plated, which, according to the power of the battery, takes from six to ten hours, but the average will be eight hours. It is fully understood that the ware must be perfectly clean, free from grease or dust before introducing them into (6) the bath. After being taken out from the plating liquid, the articles are washed off with hot water and polished on a cloth buff with crocus, rouge, Vienna lime or other polishing powder and oil.

The expense attending the nickel-plating is quite inconsiderable; spoons and forks may be coated completely with nickel for 25 cents per doz.; turrets or check holders, wheel hubs, large bits, and other saddlery trimmings, for 30 cents per doz.; a sadiron, weighing five pounds can be plated for four cents.

The operation is constantly going on; as soon as one set is sufficiently coated it is removed and replaced by another.

The main condition of nickel-plating lies in these points: 1, to have the solution always kept neutral, it is necessary to test frequently the liquid by means of litmus paper, and if the same indicates a prevalence of acid, to add sufficient caustic ammonia to make the liquor perfectly neutral; also to replace occasionally the consumed salts; 2, to have the materials to be plated always perfectly clean, which, if the goods are of iron, can be done by dipping them in a mixture of muriatic acid and water; the least scratches will prevent a complete coating.

Number 30 brass wire for small articles, and number 16 wire for larger copper articles, are used for suspending the ware.

The chloride of nickel and ammonia is much used for plating, requiring but four ounces of the salt to one gallon of water.

A simple nickel-plating apparatus, likewise in full operation, may also be described, as very satisfactory results are daily realized: 1, a bath or vat containing the usual nickel solution of double salt, three-quarters of a pound to the gallon of hot water; five gallons is applied to the porous cell which contains the amalgamated zinc pole three inches broad, seven inches deep, and seven inches long, but touching within one-half of an inch all around from the cell. The copper wire is connected, to hold suspended the articles, such as faucets, pistols, or other ware to be plated with nickel; the operation goes on at once and deposits the metallic nickel from its solutions in the space of three to four hours.

In a synopsis of Adams' claim of nickel-plating for which he obtained four patents, I find that he bases the one of August 3, 1869, on a solution of the double sulphate of nickel and ammonia, and of a solution of the double chloride of nickel and ammonia; the patent, March 22, 1870, on the solution of the double sulphate of nickel and magnesia; and in that of May 25, 1870, for a solution of the double sulphate of nickel and ammonia; while in his last patent of March 11, 1873, he claims a solution of either of the soluble salts of nickel, which must be free from the presence of potash, soda, lime, alumina and nitric acid, or either of them, and free from acid and alkaline reaction, or from either. It appears, therefore, that they are all tending to prove the character of the solutions he uses for depositing the nickel, which, however, have been very clearly described by George Gore, in 1855, and the application of the double salts are published by Smee. Booth's Dictionary, for 1852, speaks of a nickel battery consisting of either the nitrate or sulphate of nickel and ammonia being used for plating. The preparation of pure metallic nickel, whether from the ore or by recasting of such granular nickel, as is manufactured in Camden, N. J., or as is imported from the English and German manufactories, is generally considered to be a known metallurgical process. Whether the nickel metal contains some carbon or iron, if used as anode, matters little, for it does not affect at all the operation of plating.

Mr. Bequerel states that any one may apply the process which Mr. Adams has patented, without any infringement, as potash in no way affects injuriously the deposition of nickel, the double sulphate of nickel and potassa as well as the double sulphate of nickel and ammonia can easily be applied; while the special feature of Mr. Adams' patent, consists in the exclusion of the smallest quantity of potash, soda, or other alkaline earth from the bath, containing the nickelizing preparation, pure double chloride of nickel and ammonium or the perfectly pure sulphate of nickel and ammonia may safely be employed.

Nagel's process for electroplating with nickel or cobalt is likewise based upon applying the double salts of sulphate of nickel and ammonia or double salts of sulphate of cobalt and ammonia with the platinum positive pole. It consists in taking 400 parts of the sulphate of nickel and 200 parts ammonia, dissolved in 6000 parts of hot water and the ammonia of 0·909 spec. gravity, heated to 100° F., and if cobalt, but 138 parts of the sulphate of double salt are employed.

Mr. Beardslee, who is unquestionably the veteran in nickle plating in the United States, informs the author that ever since 1858, he has coated metals with electric currents; that he found the chloride of nickel with a certain quantity of ammonia to be of great service.

He attributes any failures in depositing nickel to the following requirements:

1. Nickel must have a perfectly uniform and unchanging current of electricity; a Smee battery, with a chromium negative plate, gives a powerful and constant current of electricity.

2. The nickel solutions with the chloride solutions may work better with acid instead of alkaline reaction; he quotes, as instances, that he had 2000 gallons of nickel solutions since 1868 and 1869, in constant use without any addition, but have been corrected from time to time in order to give them an acid reaction, as the tendency in working is to become alkaline.

The author begs, however, to close this pamphlet and the subject of nickel plating, by remarking that sulphate of nickel and ammonia will work better if kept under an alkaline reaction.

The following remarks, given to the author by Mr. Beardslee, are of much importance to those who wish to be fully posted:

He uses two cells of the chromium negative plate battery; the amount of battery power required for a given quantity of work to be done should be in zinc surface, equal to the surface to be quoted.

The surface of the nickel anode should in no case be less than the surface to be coated. The anode surface for a nickel solution may be much greater than the surface to be coated; and more and better work will be the result.

For a nickel solution of 40 gallons, 10 anodes of 6 × 12 inches are required, and in proportion to the greater or less quantity of gallons.

By estimating 7½ gallons to each cubic foot, we can determine the amount of solution that will be required for a vat of any given size.

The nickel anodes are connected with the negative plate of the battery, which may be either the chromium or carbon plates; the articles to be coated are connected with the zinc pole of the battery.

In one gallon of the nickel solution, a nickel anode of 4 × 6 inches is employed for coating small articles from two one gallon cells of the chromium negative plate battery.

Stolba's method of nickel-plating by means of chloride of zinc, has lately been introduced for coating iron, steel, copper, brass, zinc or lead. He recommends the chloride or sulphate of nickel as simple salts (which need not be chemically pure).

To a portion of chloride of zinc twice the volume of water is added, the mixture is then boiled, and hydrochloric acid is slowly added, until the precipitate formed by the dilution redissolves again. A very little zinc powder is added, and in a few minutes the vessel is coated with zinc wherever the liquid is in contact with it. Nickel salt is then added to it in sufficient quantity to impart a green tint to liquid. The articles to be plated are then introduced, along with a few cuttings of zinc, making as many points of contact as possible; the mixture is to be boiled for about 15 minutes, when the coating is complete.

SHAW'S GUNPOWDER HAMMER.*

Philadelphia, Pa., July 15th, 1873.

To the Editor of the Journal of Franklin Institute:

Sir:—In the issue of your valuable journal dated July, 1873, you publish an article, signed by S. R. Probasco, and reported as being part of the proceedings of the American Society of Civil Engineers at the meeting of March 5th, 1873, condemning my invention.

It is held that a patented invention is private property, and that an unfair public report on the same is incompatible with the rules of any well regulated scientific society, and I cannot learn that the American Society of Civil Engineers have in any way sanctioned the opinions expressed in said article.

Had the writer of that article intended a fair report, as information before an honorable body of scientific gentlemen, such as the American Society of Civil Engineers, he could have been considerably aided by consulting the writer, with whom he was personally acquainted, but to whom he gave not the slightest hint of his intentions; or by consultation with the foreman or operatives of several machines, working highly satisfactory, within fifty minutes of his residence. Or, if he was desirous of taking upon himself any labor to investigate the capability of the driver, he might have consulted the published reports of careful and accurate experiments, signed by the highest and most intelligent engineers in the country, viz.: W. W. W. Wood, Engineer in Chief U. S. Navy, F. C. Prindell, Chief Engineer Philadelphia Navy Yard, H. Hoff, of the Eagle Iron Works; or he might have consulted the published reports of the committee of the Franklin Institute of Pennsylvania, who had the matter in hand for a period of several months, and who recommended the Scott Legacy Medal for this invention, said medal being the highest honor they could confer. This committee was composed of the ablest talent in the Institute, viz.: Prof. Morton, President of Stevens Institute, Hoboken, N. J., John C. Cresson, Chief Engineer Fairmount Park, John Agnew (lately deceased), the great fire engine builder, and E. Longstreth, superintendant and partner of the largest locomotive works in the world (located in this city). All these reports seem to have been thrown aside, or not noticed by the author of the article in question, who has selected a badly managed machine, entirely to light for its work, and employed upon the hardest soil known to pile drivers.

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* The paper referred to by Mr. Shaw was received, amongst other matter for publication, from the Secretary of the Am. Soc. Civ. Eng., since which we learn that said paper of Mr. Probasco, was an *unofficinal* abstract of a communication made to that Society.—Ed.

Mr. Probasco's statements differ from my own personal observation. For I saw *that* machine drive 10 piles in 3 hours upon that identical work, with an average of 140 blows per pile, using 1½ oz. charges of powder per blow. These piles could have been driven by 20 blows of the gunpowder hammer had it been constructed with a view to the work to be performed, and Mr. Probasco was so informed, and is fully aware of my dissatisfaction with that machine, placed under such disadvantageous circumstances, and that I condemned *that* machine for *that* work. He might with equal propriety take a locomotive off the track and notice its working as a sample of its usefulness upon the rail.

I give below the workings of the gunpowder hammer upon the various soils. The reader will notice in Major Turpin's letter (a highly educated engineer) the very hard driving encountered, and his statement that he has driven as many piles with the gunpowder hammer in 26 hours as he could drive with the steam hammer in 20 working days. The average driving time for ordinary driving (25 feet driven) is one minute per pile. The average cost for powder is

15 cents per pile, and the average blows 8 per pile. The same number of hands are required as for a steam hammer.

The United States Gunpowder Pile Driver Company of Philadelphia, Pennsylvania, owners of the patent gunpowder hammer, offered to place a proper size machine upon the work at Parsonage Lake and guarantee to drive those same piles through that very difficult conglomerate soil in a rapid and satisfactory manner; and the contractor of the pile driving portion told me he would place there the kind of machine I recommended if the parties wishing the piles driven would pay a living price for the work; otherwise he would throw up the job—which was the final result. Hence there was no chance for the company to place a properly proportioned machine upon that work. The machine quoted by Mr. Probasco was condemned by the writer in the most emphatic terms for that work.

The following reports show the actual work done by some of our earliest constructed machines. Since which time we have added several improvements which increases their efficiency. Since writing the above, I have been handed by my friend, Mr. Holroyde, a letter from the Secretary of the American Society of Civil Engineers, stating that Mr. Probasco's published report is an unofficial abstract, and unauthorized by that Society.

Extracts from F. C. Prindell's report of pile driving at League Island, show that the average blows of the gunpowder hammer per pile is 5·2. The piles being driven an average of 19·4 feet, with an average of 8·2 ounces of powder per pile. And that the largest number driven in one hour is 12 piles. And that on experimental trial the pile was driven an average of six times greater distance per blow with the gunpowder hammer as compared to ordinary drop hammer of same weight, and falling the same distance.

THOMAS SHAW.

[*Copy of F. C. Prindell's Letter.*]

CIVIL ENGINEER'S OFFICE, U. S. Naval Station,
League Island, July 19th, 1873.

The Gunpowder Pile Driving Co. of the United States:

GENTLEMEN—In response to your inquiry of the 16th inst., requesting me to favor you with a statement of the work done by Shaw's Gunpowder Pile Driver under my supervision here, as well as my opinion of its merits, etc., I would respectfully state that about (2000) two thousand piles have already been driven by this process on the works of improvements at this station, embracing a variety of work, afloat and ashore, and all in so satisfactory a manner that preparations are now in progress for driving several hundred more with it this season.

The landing wharf (100x300 ft.) on the Delaware front is supported by heavy yellow pine bearing piles, and is close fendered for a distance of 200 ft. around its outer end with 12″x12″ oak piles, about 40 ft. long, all of which were successfully driven with your first and, in many respects, experimental machine.

The foundations for the new building now in progress of construction rest upon ordinary hemlock piles also driven by this process. All of these piles have been driven firmly into the hard gravel bottom at depths varying from 19 to 23 ft. below mean low water level, and in all cases without the slightest injury to them, the heads remaining perfectly sound and ready for copping or bedding in concrete, without loss of timber due to the brooming and splitting of the old method. The superior alignment of the pile heads by this machine, which is another excellent feature peculiar to its operation, greatly facilitates the work of copping them for wharf covering, and reduces cost of labor and material in preparing for and enclosing them in concrete for bed foundations.

In short, the superior character of the work in every respect done by this machine needs only to be seen to be appreciated, and must commend its use to the favor of engineers generally. I regard its value in this respect more than in the rapidity of its operation. Very respectfully, etc.,

F. C. PRINDELL, Civil Engineer.

ENGINEER'S OFFICE, JAMES RIVER IMPROVEMENT,
Richmond, Va., June 25, 1873.

FRANKLIN B. COLTON, ESQ. *President Gunpowder Pile Driver Co. of U. S.*

SIR :—In reply to your favor of the 7th inst., asking my views as to the merits of the Gunpowder Pile Driver, and as to its performance as compared with the ordinary machines in use for driving piles, I have to state that, after correcting some defects in the original construction of the machine, and the introduction of steel guides, its performance has been admirable and to my entire satisfaction.

Probably at no point in the United States has it been subjected to as severe a test as on James River, where the material is sand (in many instances the most trying material in which piles have to be driven), then sand, gravel and boulders, over laying granite in a decomposed state. In all the varying and hard material it has met my expectations. On one occasion, I drove 240 piles through from seven to eight feet of *sand*, overlaying decayed granite, making an average penetration of eleven feet, in 26 working hours. With my old machine, and one of the best of its kind, I would have been well satisfied to have done the same work in twenty days. You are aware that most of my work is in shoal water, and some days I can only get from three to five hours work. With me, I consider the saving of timber more than pays for a liberal allowance of ammunition. I order my piles five feet shorter than heretofore, when purchasing for my old machine. With the Gunpowder Driver, there is no breaking or mashing of piles ; they are left in the hardest material in such condition that, where needed, tenons can be cut without any loss of timber. On James River, in my work, the advantage of the Gunpowder Driver over the old machine is fully two-thirds. I have driven sheet-piling with my machine very satisfactorily.

On the Appomattox River, its performance was as satisfactory to Mr. H. D. Bird, Chief Engineer, as it has been to me. Mr. Bird has had long experience with Pile Drivers, and I make the following extract from his letter on the return of the machine to James River : "I confess that I was most agreeably disappointed in it. I take pleasure in saying that it is the best machine for the purpose I ever saw, and will drive the old Pile Driver out of existence." Several officers of the United States Engineer Corps have witnessed the operation of my machine, and have invariably expressed themselves as being highly pleased with it. I am very respectfully and truly,

W. G. TURPIN,
Engineer James River Improvement.

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EDITORIAL.

ITEMS AND NOVELTIES.

Heyl's Machine for making Paper Boxes.—By Hector Orr.*—More than seven years ago, my friend Mr. H. R. Heyl determined to make rectangular paper boxes by machinery. I heard of his intention soon after the inception of the idea, and I promised to introduce the contrivance at a monthly meeting of the Franklin Institute as soon as it was presentable. I heard of the progress of the enterprise from month to month, and from summer to winter: then into the second year; the third, and then onward rather indefinitely. At length, in January, 1871, Mr. Heyl brought me this box which I now show you, as one of the first lot actually made by the long-sought machine. We did not then exactly fix a day for bringing it here, yet felt sure that it would arrive soon. But the months began to speed along again; summer arrived; the equinox and the September meeting were true to their accustomed dates; the paper-box automaton, however, still continued to "turn up missing;" until I began to suspect that the express wagon with its coveted freight, instead of reporting at the Hall, North Seventh street, had sped away into the "land of promise" once more.

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* Read before the Franklin Institute, September 17, 1873.

That machine (which is not here, but which I hope we all shall have the opportunity to see sometime) was intended to make rectangular boxes by paste, paste-board and slips of paper, applying much of the means formerly used for the purpose, and imitating in a surprising manner even the motions of the human operator. The box, as you may prove, is both neat and strong, and can be made at a rate full *ten times* as fast as that of the most expert girl or boy. I have seen several—yes, many—ingenious machines through the past fifty years, topping off thus far perhaps with the Bullock Printing Press, but I must admit that among them all this automatic Paster deserves its full room in the front rank, for its series of complex movements following in most attractive harmony to a triumphant result.

This admirable contrivance, however, the child of patience and perseverance, is already measurably superseded. (I hope yet to see it fenced in like the old Independence Bell, in the parlor of the owners of the patent; but for the present we must turn from it.)

About the middle of last February, I found at my office a notice that the "improved" Box-making Machine would be running that afternoon in West Philadelphia. It was a day of most ungracious weather, such as even the clerk of Probabilities is unable to specify. Its the temperature just between freezing and thawing, and the surface of ground covered with dirty snow. But what is two miles of snow slush as an impediment, when there is an ingenious machine to be seen at the end of the journey? I can say that "I conferred not with flesh and blood" as to my conduct, but within the next hour was on my way to the factory, at whose threshold I met Mr. Heyl, who declared the burden of the day completed by my arrival. I there saw a machine making such boxes as *this*, at the rate of 3,000 per hour. It is a match box; and I saw the slips of wrapper lifted singly and shaped; then fastened by delicate staples of iron wire, which were made and riveted by the machine; and then said enclosures were touched with glue and sprinkled with sand, and fell down before me ready to be filled with matches!

This machine dispenses altogether with paste in the formation of the box—a great desideratum on more than one account. For besides the gain in speed thus secured, the getting rid of the moisture identified with the paste is a most important achievement; for the delay in drying the box, caused by damp weather, often frustrates the shipment of large invoices, if not a whole season's supply, of goods. We have just experienced a spell of moist weather in which pasted boxes might actually mildew before they would dry, and in a damp state they would injure if not ruin the goods packed in them. In pasted boxes, also, under a high temperature and damp atmosphere, insect life is generated, which destroys the proper strength of the box and also seriously damages confectionary or dried fruit contained therein.

These were the considerations which induced Mr. Heyl to modify his first machine, and through various changes he now presents it as making a neater and stronger box than that made by hand, and produces by one machine the amount of work hitherto requiring the labor of *seventy-five* persons.

Besides the special purpose of this invention, in thus greatly adding to the supply of an article indispensable to much of the small wares of trade, the improved mode of fastening the edges offers new proof of the *power of impact* exerted at a right angle with the surface. These minute staples are composed of fine soft wire hardly more rigid than a thread of waxed sewing silk. This wire is wound on a spool, from which the proper length is drawn for each box, and the staples are formed and brought each to its place at right angles with the box material, and at the right moment are made to puncture the wrapper or board, and are immediately clinched on the opposite surface. I think the most adroit set of fingers among us would fail to force or coax the point of this wire through even a thick wrapper, in less than several minutes, while this machine, besides all its other work, does this sixty times per minute. It furnishes one more instance of an act which,

> " *When* it is done,
> 'Twere well it were done quickly."

Indeed, unless it be done quickly, it cannot be done at all. If this admission shall furnish some future annotator of Shakspeare with an argument to prove that his idol knew all about the making of paper-boxes, it will not be more far-fetched than some of the feats already ascribed to him.

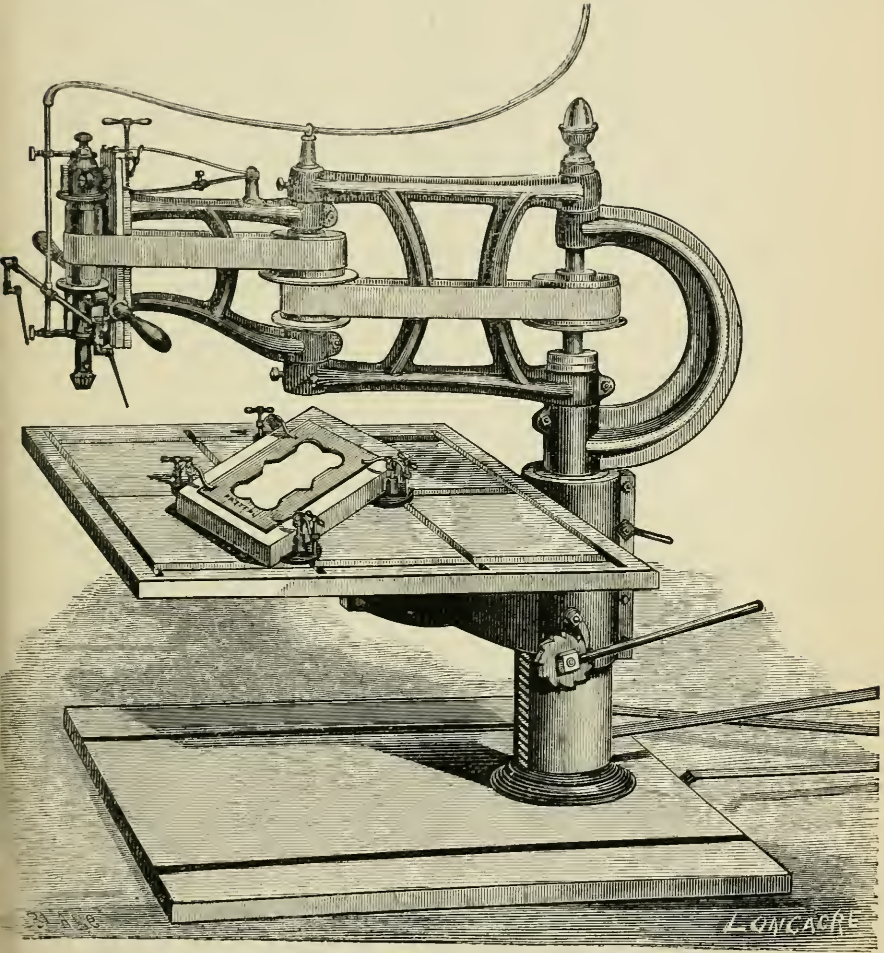
I thus place before the Institute a full seven years' task completed, and that completion embracing an emphatic triumph of patience and skill; presenting a useful branch of business advanced in style and strength, and whose production is multiplied full seventy-five times.

And now I shall give place to another *talking* machine, which I expect shall *speak for itself;* I having that intruding peculiarity which excels in speaking for others.

The Gear Stone Cutting Machine.—At a recent meeting of the Franklin Institute, Col. A. S. Gear gave a description of the machine of which the accompanying plate gives an illustration.

The speaker referred to the need which had long been felt by architects and builders for proper machinery for dressing, decorating and ornamenting stone, by which something of the present excessive cost, which has heretofore been inevitable in the employment of hand labor, might be avoided; and consequently the use of stone for architectural purposes become more general. After a brief enumeration of the difficulties in the way of the successful solution of the problem, and the reasons which prompted the selection of the diamond as a cutting agent, the speaker gave the following description of the machine:

It rests upon and is strongly connected with an iron bed-plate as a foundation. The bed-plate is in shape a parallelogram, not much longer, however, than its width. A heavy iron standard rises at one end of the bed-plate, to which all the rest of the machinery is attached. A short distance above the lower bed plate is a second bed-plate, which is adjustable, up or down, by means of a rachet-wheel and lever, and is in the easy control of the operator, or can be turned out of the way entirely when it is necessary to use the lower bed-plate for heavy work—the lighter work being all done on the upper bed-plate or table. Above this bed-plate, and attached to the upright shaft, are the more important parts of the machine. This portion of the machine is in two general parts, strongly and firmly made, and provided with pulleys that give great rapidity to the cutting or moulding tools, the motions of which are all circular or rotary. This part of the machine, for purposes of description, may be called the human arm, its entire movements strikingly resembling those of the human arm, the most perfect and the most beautiful motion in the whole realm of nature or art, and being far the most varied and important. At the extreme end of the arm is its hand, which firmly grasps the various tools it operates with, and holds them rigidly to their place. The articulations of the machine, so to speak, being at the shoulder—its shaft attachment—and at the elbow, where the two parts are connected together, and at the wrist, where the hands grasp the tool, the movement of the tool is completely, and with the utmost ease, under the control of the operator. A pattern is used in cutting ornamental work, which is simply an outline of the design desired. Both the pattern and material being operated upon, are fastened to the table by adjustable clamps. Every little adjustment has been perfected with a view to rapid changes, and the spindle containing the cutting tool may be run at almost any angle.



GEAR STONE DRESSING MACHINE.

The tools employed are made of steel, studded with carbons or black diamonds, which have been successfully used for rock-boring for years, the diamond from such use showing but little if any wear after being used from twelve to eighteen months.

Many attempts have been made to set and hold diamonds in saws, discs, etc., but with more or less difficulty, from the fact that the diamond cannot stand concussion or strain, and if subjected to either will frequently break or become loosened. The diamonds in this stone machine tools are set so as to avoid these difficulties. Their action upon the stone is of a shearing or drawing nature, and scratches but little if any larger than those that might be produced by the point of a pin, are made by these tools, consequently they receive no strain sufficient to loosen or remove them, or concussion so severe as to break them. They revolve so fast and make so many, almost innumerable and rapid scratches, that the work is accomplished with almost incredible expedition.

I employ a wedge-shaped dressing or surfacing tool. The diamonds in this tool are set in the same manner as in the moulding tools. Above the thin cutting edge there is placed a rotary wedge which in its operation cuts into the edge of the stone, removing the stone the thickness of the cutting edge. After cutting under a mere trifle the wedge strikes it and splits or breaks it off, it making no difference whether a quarter of an inch or four inches in thickness are to be removed. Stone may be dressed with this tool just as it comes from the quarry.

All work required or desired in producing ornamental stone-work—in a word, everything heretofore produced in wood by machinery—may now be done in stone.

I have obtained several patents in this country on the machine and tools—several have also been granted by European governments, and others applied for. The machine is now owned by a company organized under the laws of Massachusetts, called the "Gear Stone Machine Company."

The Commission on Steam Boiler Explosions.—The following official information, upon a subject of much interest to engineers and the public in general, has recently been made public. The commission appointed by the United States Government to inquire into the causes of steam boiler explosions, in order to determine by actual experiment the best form and construction of safety valves which shall operate automatically in relieving the boiler from the pressure of the steam, or with certainty to automatically prevent any increase of pressure above that at which the valve shall be set, invite persons claiming to have valves of superior efficiency to submit one to the commission for examination and testing. All valves presented must have an area of five square inches in their discharge openings, and the flange for attaching to the boiler must be eight inches in diameter, flat face without bolt-holes; valves to be sent, charges prepaid, and communications on the subject addressed to Addison Law, Supervising Inspector, No. 23 Pine street, New York city, before October 10th, 1873.

The commission at a recent meeting held at Washington, decided to call for co-operation and advice, in the performance of their allotted duties, upon engineers, inventors and scientific societies. The points upon which the commission solicit information are the following: 1. Explosions caused by the gradual increase of steam pressure. 2. Those caused by low water and over-heating of the plates of the boiler. 3. Those caused by the deposit of sediment or incrustation on the inner surface exposed to the fire. 4. Those caused by the generation of explosive gases within the boiler. 5. Those caused by electrical action. 6. Those caused by the percussive action of the water in case of rupture of the boiler in the steam chamber (the Clark and Colburn theory). 7. Those caused by the water being deprived of air. 8. Those caused by the spheroidal condition of the water. 9. Those caused by the repulsion of the water from the fire surfaces or plates.

Communications intended for the commission, upon these or related matters, should be addressed to Mr. Geo. W. Taylor, the Secretary of the Experimental Commission, at the Treasury Department, Washington, D. C.

The St. Louis Bridge.—A local paper affords the material for the following concerning the progress of this undertaking:

The difficulties to be encountered in putting in the connecting tubes to complete the span of the first arch of the bridge are not generally understood, hence there is a little surprise amongst a large portion of the public on account of the delays which have occurred. At present the weight of the superstructure is supported by the cables, and whilst that is the case, the expansion and contraction of the tubes by heat and cold is of no consequence, but when it comes to putting in the last tubes, expansion and contraction play an important part. When the connection is once made and the supports removed so that the arch is self-sustaining, a new element is introduced—the contraction due to pressure.

When the cables are slackened, the arch at the centre will, from this cause, settle about three inches. Provision has been made for this by increased length in the tubes, all the calculations being based on a temperature of sixty degrees. At that temperature it is known to the sixtieth of an inch what would be the intervening space between the approaching tubes, and the last points have been diminished accordingly.

Only once since the workmen have been ready to put in these last tubes has the temperature been favorable. On one morning recently, the conditions were favorable, but owing to some inexplicable tardiness on the part of the workmen, the opportunity was lost. One tube was put in and fitted to a nicety. In the meantime the sun shone on the bridge, and when it was attempted to place the other tube, it would not go entirely to its place, being about a thirtieth of an inch too long, on account of the expansion of the tubes in place. An attempt was made to drive it into place with sledges, but without effect. In consequence of not being able to put the second tube in place, the first one had to be taken out again, and a more favorable opportunity waited for.

The prospect being that a delay of several days would occur before the exact temperature required would be obtained, it was determined to try a little strategy in the case by reducing the temperature artificially. Accordingly, about 45 tons of ice were applied to the tubes and bound on by many yards of gunny bagging, forming perhaps the most extensive ice poultice ever used. On the afternoon of the same day the expansion had been reduced about two inches, and our informant concludes it was expected that in a few hours more the contraction would be sufficient to admit of the tubes being put in place. The successful execution of this experiment we hope to chronicle in a future number of the Journal.

The East River Bridge.*—The New York tower of the East River Bridge has nearly reached the level of the roadway, and the view now obtained from its summit is the same as will be had from the bridge when completed. The whole of New York, and the greater part of Brooklyn and Williamsburgh, constitute but a portion of the prospect which is seen from this elevated position. On a clear day one can easily see some of the villages on the Hudson, portions of New Jersey, Staten Island, and New York harbor. On the Brooklyn side, the three piers which extend above the roadway, and are to support the cables, have been brought up to the springing line of the arches.

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* The Iron Age.

The laying of masonry on the New York tower at present proceeds but slowly, on account of the iron work necessary at this stage of the construction. Nearly a week is now consumed in laying a single course of masonry. At the seventieth course the use of iron cramps was begun. The cramp consists of a bar of round wrought iron, about 1½ inches thick and three feet long, three inches at each end being turned down at a right angle to its length. Its office is to bind together two adjacent stones. A hole is cut in the top of each stone, into which the ends of the cramp are inserted, and a groove is cut on the upper surface of the stones upon which the cramp lies. The holes into which the ends of the cramp are inserted are filled with cement, and a strong bond is thus secured. Thirty-two of these cramps were placed in the seventieth course, and the number has been gradually increased as the tower was carried upward ; the seventy-ninth course contains sixty-four cramps. They are laid parallel to the face of the tower, that is, at right angles to the direction of the bridge. Their object is to counteract the tendency of the tower to spread where the weight of the bridge comes to bear upon it.

To provide still further against the tendency of the tower to spread, the four courses below the roadway, viz.: the 76th, 77th, 78th and 79th are strengthened by strong eye-bars, consisting of flat iron five inches in width by one in thickness. There are two of these in each course, one in the front and the other in the rear, each extending nearly the whole length of the tower. The bar is secured to the masonry at each end by pins three inches thick and two feet long, passing through an eye in the bar, and extending nearly a foot into the masonry above and below. Each bar really consists of two bars joined in the centre and firmly bound together by iron wedges. A groove is cut in the upper surface of the course of masonry on which the bar lies, for its reception, so as not to disturb the level of the course above.

In the 79th, 80th and 81st courses are laid a series of compound steel bars ten inches wide by two in thickness, designed to prevent the swaying of the bridge from side to side from the action of the wind or any other cause. There are two of these bars in each course, one at each end. Each bar is composite, consisting of three sections connected together at their ends by splice plates and bolts. The outer one of the three, or that which projects from the face of the tower, is straight, and has such an angle with the face that, if continued, it would strike the bridge about half way across. The middle section is curved, and the third section, which is spliced to this one, projects sufficiently beyond the rear of the tower to allow a pin to pass through an eye cut in its extremity. It makes the same angle with the rear of the tower as the front section does with the face. Each of these compound bars weigh 2½ tons. As before stated, there are three tiers of such bars at each end of the tower; their ends project beyond the masonry, and a pin six inches thick driven through the eyes in each set of projecting ends secures them firmly to the tower, and combines the three tiers at each end of the tower in one powerful link. Two heavy cables are fastened to these bars, one to each link. Each cable proceeds from its link to the centre of the other edge of the bridge, and then passes over to a corresponding link on the opposite tower. A series of smaller irons, intended to supplement these bars, are also fixed in the tower, and from these are to extend cables to a point half way between the middle of the bridge and the shore.

A series of eye bars extend through the tower a few courses below the roadway, and parallel to the axis of the bridge; they are directly under the future position of the bridge trusses, and are to be connected with tension cables, which extend diagonally upward to the lower surface of the bridge. The function of the latter is to give a greater degree of rigidity to the structure. The connecting walls of the tower are cut at the 80th course, in order to receive the trusses which rest upon and fit into that course. The tower, it will be remembered, consists virtually of three towers joined by connecting walls. At the 81st course the latter are discontinued, and the three piers carried up independently, as can now be seen in the Brooklyn tower. The centre pier of the three is built entirely of dimension stone, even the backing being constructed in this manner. A very great degree of strength is required of this pier, inasmuch as it is to support two of the main cables, and is narrower than the two exterior piers, each of which support but one cable. The latter, however, are also to be constructed largely of dimension stone. There are now about forty men employed on the New York tower; of these ten are engaged in cutting the holes and grooves in the stone, and five in laying the masonry.

As soon as the 80th course is completed the method of carrying on the work will be completely changed. The old boom derricks will be taken down, and their places supplied by a pair of balance derricks for the exterior piers and a traveling crane for the middle pier. The reason for not using a derrick in the latter case is that it would be necessary to have a well-hole in the centre of the pier, in which to place the mast, and the pier would be thereby weakened. As great strength is required in this place such an evil is avoided by the use of a traveling crane instead of a derrick. Both the crane and one of the derricks are now completed, the other derrick being nearly ready. The boom of each derrick is thirty feet in length, and the span of the traveling crane is about eighteen feet. The new engine for hoisting stone, etc., to the top of the tower is also ready. It has two hoisting drums, both on the same shaft, and while one drum is engaged in hoisting to one end of the boom, the other is unwinding its rope and allowing the hook to descend at the other end of the boom. As soon as the 80th course is laid all the machinery formerly used on the tower and the docks will be rapidly dismantled, and the new appliances substituted. Every portion of the machinery exposed to heavy strains is tested once every day, and as the work approaches completion, all the calculations connected with it are made with greater exactness.

The four anchor plates for the Brooklyn anchorage are already in position. They are laid at a depth of 24 feet below the surface of the ground, and six courses of masonry have been laid upon them. About twenty buildings have been torn down to make room for the anchor walls. In all the calculations respecting the strength of the various portions of the bridge one-sixth of the theoretical strength has been taken as the maximum, in order to leave a wide margin of safety.

The Vienna Patent Congress.—The following is the text of the resolutions adopted by the recent International Patent Congress which met at Vienna: 1. The protection of inventions should be guaranteed by the laws of all civilized nations, because, (a) The sense of right among civilized nations demands the legal protection of intellectual work. (b) This protection affords, under the condition of a complete specification and publication of the invention, the only practical and effective means of introducing new technical methods without loss of time, and in a reliable manner, to the general knowledge of the public. (c) The protection of invention renders the labor of the inventor remunerative and induces thereby competent men to devote time and means to the introduction and practical application of new and useful technical methods and improvements, and attracts capital from abroad, which, in the absence of patent protection, will find means of secure investment elsewhere. (d) By the obligatory complete publication of the patented invention, the great sacrifice of time and of money which the technical application would otherwise impose upon the industry of all countries, will be considerably lessened. (e) By the protection of inventions, secresy of manufacture, which is one of the greatest enemies of industrial progress, will lose its chief support. (f) Great injury will be inflicted upon countries which have no rational patent laws, by the native inventive talent emigrating to more congenial countries, where their labor is legally protected. (g) Experience shows that the holder of a patent will make the most effectual exertion for a speedy introduction of his invention.

2. An effective and useful patent law should be based on the following principles: (a) Only the inventor himself or his legal representative, should be entitled to a patent. (b) A patent should not be refused to a foreigner. (c) It is advisable, in carrying out these principles, to introduce a system of preliminary examination. (d) A patent should be granted either for a term of fifteen years. or be permitted to extend to such a term. (e) Simultaneously with an issue of a patent a complete publication of the same should take place, rendering the technical application of the invention possible. (f) The expense of obtaining a patent should be moderate; but in the interest of the inventor, a progressive scale of fees should be established, enabling him to abandon, when convenient, a useless patent. (g) Facilities should be given by a well organized patent office to obtain in an easy manner the specification of a patent, as well as to ascertain what patents are still in force. (h) It is advisable to establish legal rules, according to which the patentee should be induced, in cases in which the public interest may require it, to allow the use of his invention to all responsible applicants for an adequate compensation. (i) The non-application of an invention in one country shall not involve the forfeiture of the patent, if the patented invention has been carried into practice at all, and if it has been rendered possible for the inhabitants of such country to purchase and make use of the in-

vention. (k) In all respects, and particularly as regards the proceeding in the granting of patents, the Congress refers to the English, American and Belgian patent laws, and to the draft of a patent-law prepared for Germany by the Society of German Engineers.

3. Considering the great difference in patent administration, and the altered international commercial relations, the necessity of reform is evident, and it is of pressing moment that the governments should endeavor to bring about an international understanding upon patent protection as soon as possible.

4. The Congress empowers the preparatory committee to continue the work commenced by this first International Congress, and to use all their influence that the principles adopted be made known as widely as possible, and carried into practice.

5. The committee is likewise authorised to endeavor to bring about an exchange of opinions on the subject, and to call, from time to time, meetings and conferences of the friends of patent protection.

6. To this end the preparatory committee is hereby appointed to act as a permanent executive, with power to add other members to their number, and to appoint the time and place for the next meeting of the Congress, in case such a meeting should be considered necessary for the promotion of the foregoing resolutions.

Phosphor-Bronze.—The industrial exhibitions abroad have afforded an opportunity for the display of many interesting and valuable efforts in behalf of industrial progress. As of special note we may refer to the display of objects in phosphor-bronze, of which much has lately been said.

To recall this subject to mind it will be well to state that the metal in question is a new kind of bronze, patented by Messrs. Montefiore and Kunzel, and is composed of varying proportions of copper, tin and phosphorus. The alloy is capable of being made tough and malleable, or hard, at will, according as the proportions of the materials are varied. The presence of phosphorus in its composition permits of making very clean and sharp castings. Dr. J. R. Mann, on behalf of the Society of Arts, gives the following list of exhibited objects in this metal, which affords an excellent illustration of the various uses to which it is designed to put it. The list comprises heavy bearings of machinery, cog wheels, guns and cartridge cases, wire, tuyeres for blast furnaces, and ornamental castings of various kinds; tools and appliances, such as hammers, knives, scissors, hinges, locks, keys, bells, netting, seives, &c.

A contemporary (*Iron*), referring to the subject, remarks amongst other things; the new alloy which has been recently brought before the public is likely to be much patronized, especially in manufactures where steel is useless or dangerous. The reasons given by the patentee are that it can be made, according to the wish of the operator, more ductile than copper, as tough as wrought iron, or as hard as steel; it possesses great fluidity; its homogeneity is complete, and its grain is as fine as that of cast-steel. It may be perfectly controlled to suit any particular purpose for which it is intended, and it can be made either hard or soft, tough or brittle, and its ductility, elasticity, or hardness can be regulated with the most perfect accuracy. Unlike other alloys it can be re-melted without any material loss or alteration of its quality, while heavy steel castings, when worn out or broken, are comparatively worthless.

A great variety of objects hitherto worked in iron and steel may now be cast in the new alloy, and in a great many cases they require only a polish to make them ready for use; besides which they do not corrode as do articles of iron or steel. The great fluidity, compactness and fine grain, as also the beautiful color of the metal, especially recommend it for the decorative art, while the perfection of the castings greatly reduces the cost of chasing and finishing. This alloy stretches more than copper, or any of its ordinary compounds, and plates of it have been reduced by a single cold rolling to one-fifth of their thickness, the edges remaining perfectly sound and without crack.

By order of the Prussian Ministry of Commerce, experiments have been made with the various kinds of phosphor alloy, the object of which was to ascertain the resistance of the metal to repeatedly applied strains or pulls, and also to bends of a given force.

The first bar fixed on the stretching machine resisted 408,230 pulls of 10 tons per square inch, while a bar of ordinary bronze broke before the strain of 10 tons had been reached. Another bar withstood 147,850 pulls of 12½ tons per square inch. Still more favorable results have been obtained on a machine by which the test bar was bent as often as 40,000 times per day. In this instance it resisted 862,980 bends of 10 tons per square inch, while the best gun metal broke after 102,650 bends of the same force. Another bar which was being tested withstood 1,260,000 bends of 9 tons force per square inch without showing signs of weakness.

The St. Louis Tunnel.—The construction of the great railroad tunnel in St. Louis is steadily progressing. Work upon this enterprise was begun last November, but owing to an inclement winter very little progress was made until about the middle of March, since which time the progress made has been satisfactory even to its most sanguine friends.

The span of the arches of the tunnel, of which there are two, is fourteen feet clear, and the height seventeen feet. The arches have a depth of five lengths of brick springing from a wall of solid stone, whose foundation is six feet thick; the side walls are five feet thick to the spring line, above which the thickness of the wall is four feet; the centre wall is three feet in thickness. All the brick-work and masonry is set in hydraulic cement.

The work thus far done is in figures as given by a local authority: 12,500 yards of stone masonry; 2,500 yards of brick masonry, and 95,000 yards of excavation. The prospects are that the bridge and tunnel will be opened simultaneously.

A Valuable Record of the International Exposition.—An editor of London *Engineering* is constantly at Vienna, with an assistant editor, and the enterprising publishers of that periodical are proposing to expend several thousand pounds upon the illustration of the articles prepared by them in reference to the great exhibition.

This valuable material will subsequently be published in book form, immediately after the close of the *Ausstellung*. We shall look for its appearance with very great interest.

Editorial Correspondence.

To the Editor of Journal of the Franklin Institute:

Dear Sir,—My attention has been called to an article of Mr. Mott on "Lightning and Lightning-rods," published in the August and September numbers of the "Journal," which contains many theories and notions at variance with those published by myself about a year since.

Mr. Mott says: "Thus his Majesty's ship Dictator was struck and damaged by lightning at Martinique, in the year 1794, during fine weather and a clear sky."

When effects are produced without cause miracles are wrought, and this is the latest recorded instance of a miracle. It is difficult to understand how any one who possesses any familiarity with the laws governing the propagation of the electric current, can believe that such an occurrence ever took place.

"The return stroke often kills men and animals, or destroys buildings which are at the time at a great distance from the place where the direct discharge occurs."

I have no hesitation in emphatically asserting that there is no such thing as a "return stroke" in an electrical discharge. There is a general inductive disturbance, or recombination, whenever disruptive discharge takes place; but it is simultaneous with the discharge, and not an after result, and never "kills men and animals or destroys buildings which are at the time a great distance from the place where the direct discharge occurs."

In speaking of the effect and virtue of points over knobs or balls, my experiments show the very opposite of what he states, to be true, and consequently I can neither appreciate nor subscribe to his remark or conclusion that, "Hence it (a point) may prevent a disruptive discharge which might otherwise occur."

On the evening of the 4th of July, 1872, a thunder-storm passed over this city. Within the space of an hour over one hundred buildings were struck by lightning, or the effects of the lightning were noticed in over a hundred different places, leaving out many, probably a greater number, where the effect was unnoticed, or no damage produced. The discharges or flashes of lightning occurred as often as once per second during a portion of this hour. There were at least five thousand pointed rods in this city, and how much did they "produce an escaping current," or "prevent the accumulation of electricity," or neutralize the charged cloud"? Probably they did their level best, and prevented a discharge occurring oftener than once per second. The above example affords a practical illustration of the ability of points to silently discharge the accumulated electricity of the clouds, the earth, or the "return stroke," or the whole combined. Mr. Mott says "points are of vital importance before the instant of discharge arrives," and he might add, of no account when they occur.

"An improper termination of a lightning-rod is to connect it with the gas or water pipes of a city or village beneath the surface of the earth. Theoretically, it is the best possible termination; practically, one of the very worst," &c.

Mr. Mott may connect a rod to earth in his way, and throw in any desired amount of charcoal. I will connect the same rod to a gas or water pipe, and then apply a current to the rod, and demonstrate that this current goes to the pipes in at least the proportion of a thousand to one.

The author, further on, refers to Mr. Crosse's experiments, whereby he discharged fifty Leyden jars twenty times a minute, accompanied by reports as loud as those of a cannon." This experiment was probably performed about the time the Dictator was struck, "during fine weather and a clear sky."

I will only remark, in conclusion, that it would have been more satisfactory had the author adopted the phraseology of many parts of my paper without interpolations.

Yours truly, DAVID BROOKS.

Bibliographical Notices.

A Treatise on the Construction and Operation of Wood-Working Machines, including a History of the Origin and Progress and Manufacture of Wood-Working Machinery. By F. RICHARDS, Mechanical Engineer.

We can fully endorse the following very flattering opinion of the work in question, which is expressed by our esteemed contemporary, "Engineering":

> With the exception of a very few imperfect articles in Encyclopædias, two or three papers read before scientific societies, and the description of special machines contained in patent specifications and in the pages of technical journals, such as our own, the subject has been left untouched; and until the appearance of the book now before us, there was, so far as we are aware, none that could be referred to for information as to how wood-machines should be constructed and managed. Under these circumstances, Mr. Richards' Treatise is doubly welcome; it is welcome in the first place because it supplies a want, and in the next place because it supplies it well. . . . . . Mr. Richards devotes two sections of his work to a consideration of wood-working machinery generally, and to an explanation of the principles that govern wood-cutting; these explanations being accompanied by data concerning hand-power operations and the performance of the same work by machines. . . . . It contains information that will be appreciated by a large circle of readers besides those specially interested in the construction of wood-working machinery.

Civil and Mechanical Engineering.

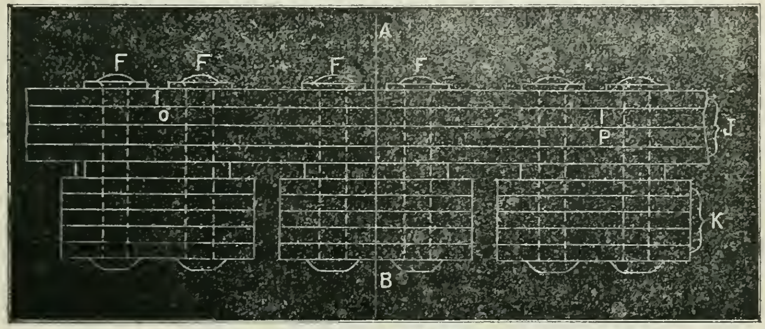
BELTING FACTS AND FIGURES.

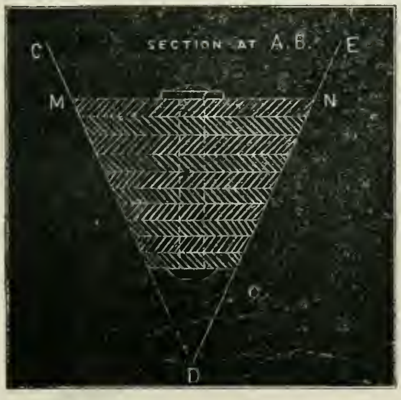
By J. H. Cooper.

(Continued from Vol. LXV, page 327.)

Underwood's Patent Angular Belting.—This driving belt consists of a number of narrow leather bands, laid a-top of one another, lapping and breaking the joints in order to secure the greatest combined strength.

To the under side of this compound band are fastened short piles of leather, of equal length, forming blocks, each secured to the band by two iron rivets, as shown in this sketch:





The four bands, J, are continuous, the five pieces, K, and shorter pieces, I, interposing, are held together by the rivets, F; all are shaped to the angle C D E, which is the correct angle of grooves for the wheels.

The length of the blocks is made as short as construction will permit, in order to increase the surface of contact while bending in the groove of the wheels; the pieces I are made shorter to give more flexibility to the band, for which also the blocks are separated by a narrow space.

The elasticity of the leather is sufficient to allow of the necessary bending of the four united bands without injury to the fibre, as it is not intended to use this belt over pulleys of small diameter.

The four bands, J, thus constituting the "wrapping connector" and tensional strength of this system, while the blocks K form the frictional wedges, so to speak, and the sloping edges of all in the angle of the groove contribute to the great adhesive power possessed by this driving belt.

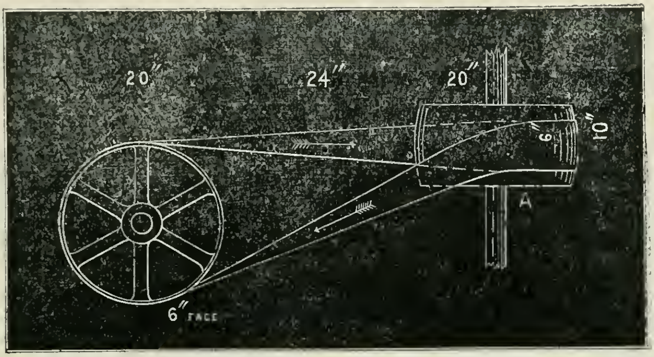
The ends of this belt are joined by bevelling the opposite faces of the part J for 18 or 20 inches of its length, and then uniting the whole by bolts having washers and nuts at F, and with heads inside, similar in size and position to the rivets; or the separated strands may be joined, the top one say at O, the next one at P, and in no case having more than one joint between any pair of rivets.

We have a practical illustration of the driving capacity of this kind of belt in the N. H. and N. Y. Railroad shops, at New Haven, Conn., where a 22-inch double leather belt of Hoyt's make, weighing 2½ lbs. per square foot, running on pulleys of 6 ft. and 4 ft. diameter, and 16½ ft. distant between centers of pulleys, with a quarter twist, and slipping under a load of 75 to 80 horse-power, with noise which could be heard 1¼ mile away, was replaced by two 2½ inch angular belts, on V-grooved wheels of same diameter. After 16 months of running, one of the angle belts was removed. This, of course, put all the work on the remaining one, and this one carried the whole load with apparent ease. Afterwards one-third more work was done by this belt without slipping, visible straining or injury.

Twenty inches length of the 2½-inch belt weighs 2 lbs. 21 inches of the 3-inch belt weighs 3 lbs. M N is the breadth.

The Quarter-Twist Belt.—When two shafts are at or nearly at right angles with each other, and not in the same plane, and it is desired to drive one from the other by two pulleys only and a connecting belt, experience has proved that certain conditions are necessary. In the first place, the distance between the near faces of the pulleys must not be less than four times the width of the belt. The pulleys A and B should be so placed that the belt will lead from the face of one to the center of the face of the other, that is, so that *a plane passing through the center of the face of one pulley will be tangent to that part of the face of the other from which the belt is running.*

The following diagram gives the position and proper proportions referred to:



The pulley A, from which the belt deflects, should have a wide face than B, in the proportion of 10 to 6, and should be more rounding on the face than is usual, and the pulleys should be as small as may be to do the work, and should be of nearly equal size.

The superintendent of Cedar Point Iron Company, Port Henry, N. Y., says, in reference to the comparative merits of steel and iron wire ropes for hoisting purposes:

"We have used iron and steel wire ropes extensively at our iron ore mines, and our experience in hoisting from 1000 to 1500 tons gross per day awards the superiority by all odds to steel. One steel rope lasts us, on an average, as long as six iron ones.

"We attempted to run them on same sheaves as we had used for iron ropes, and found in some cases that the steel rope would cut one inch into the cast-iron sheaves in one or two months of use.

"Our sheaves now are lined with wood, which entirely obviates every difficulty in the use of steel, and of course is equally to be commended for iron." Jan., 1873.

Rule for New Length of Belt when Size of Pulley is Changed.— Take three times half the difference between the diameters of the pulleys, and the result will be the length of belt to take out or put in. For instance, if you wish to change from a 16-inch to a 20-inch pulley, the difference is 4 inches; then $\frac{3 \times 4}{2} = 6 =$ the length of belt required.

In case the belt wanted tightening before, make the necessary allowance on the piece.—J. B. DOOLITTLE, *Sci. Amer., Jan. 25th,* 1873.

AN ELEMENTARY TREATMENT OF ZEUNER'S SLIDE-VALVE-DIAGRAM.

By HUGO BILGRAM.

The popularization of science being one of the objects of this Institute, it will, perhaps, not be amiss to bring before you in a new and purely elementary form a rather old subject, the Slide-valve-diagram.

One of the most important parts of the steam-engine is the Steam-Distribution-Valve. The slide-valve, moved by an excentric, as invented by James Watt, with its modifications, has so many advantages above any other form of distribution-valve, on account of its simplicity, durability and limited dimensions, that almost every competition was decided in its favor. But, although it was in use since more than a century, yet its action and the relation which the dimensions and the positions of the different acting parts bear to each other and to the resulting steam-distribution has been thoroughly studied only about 25 years ago. Because the algebraic equations which represent the action of the valve are of a complicated character, some distinguished professors have devised the construction of geometrical diagrams, which are a clear and comprehensive representation of the process of steam-distribution by the slide-valve. These great and valuable attainments, however, are accessible only to such persons which had the opportunity to study the higher branches of mathematics, as these diagrams have been obtained by their aid, and for this reason they are less frequently applied than their merits admit. Persons who in defiance of this difficulty desire to make use of these elaborations of our great thinkers are obliged to commit to memory more or less complicated rules without having any conception of their whys and wherefores. It is quite natural that under such conditions even comparatively simple rules appear complicated and are apt to be forgotten or confounded. An attempt to give an elementary explanation of one of these diagrams may therefore be justified, and if successfully accomplished may be valuable to designers, and even to mechanics engaged in the manufacture of steam engines, and to engine tenders. The diagram to be explained is that devised by Prof. Zeuner, which, in most respects, is preferable to any other diagram constructed for this purpose.

The following considerations relate to horizontal engines of the usual construction, or, to speak more general, to such engines in which the connecting-rod and the excentric rod operate in parallel directions. Other engines for which this condition is not fulfilled, for instance such with a beam, have to be compared to horizontal engines in the manner indicated further below.

I suppose I need not explain the construction of the slide-valve represented in Fig. 1. If this valve occupies its middle position, its face not only covers the two steam-ports, but it overlaps them, *a b* being the outer and *c d* the inner lap. To facilitate the explanations we may term "positive" a motion to the right, and a reverse motion "negative." The port at the right-hand side will be in connection with the exhaust-canal when the distance of the valve from its middle position surpasses the extension of the inner lap, while the other port will be open for admission of full steam only after this distance is greater than the outer lap. If at any time the deviation of the valve is known, the width of the formed aperture for either admission or exit of steam can easily be determined by subtracting the respective lap from this deviation. Only after the port is completely uncovered, a continuation of the motion of the valve can no more increase the section of the opening, which obviously never can exceed the width of the port. Such a surplus of deviation only tends to lengthen the time during which the steam can pass through the port without any hindrance.

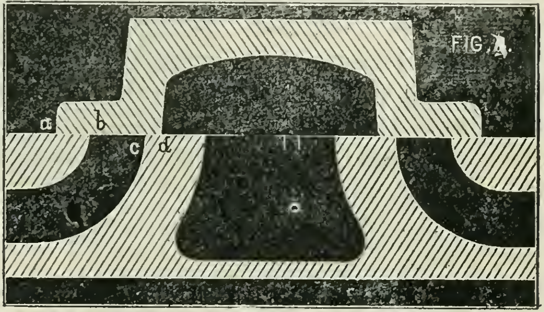
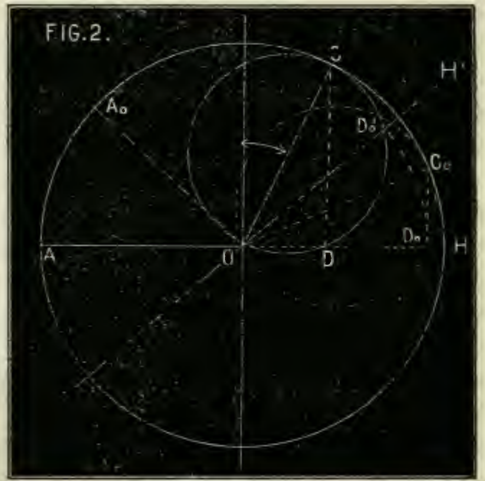


Fig. 1.

The object of our next pursuit is to find the deviation of the valve for any given position of the piston, or of the main shaft, by a simple method.

The excentric, which has the purpose of moving the valve, acts like a crank whose length is equal to the excentricity, and it is keyed to the main shaft, forming an obtuse angle with the main-crank. In Figure 2, O represents the centre of the main shaft, OA the direction of the main-crank and C the centre of the excentric disc. (The scale of Figs. 2, 4 and 5 is twice as large as that of Fig. 1).

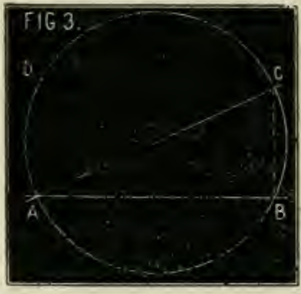
FIG. 2.



The length of the excentric-rod is from 20 to 30 times greater than the excentricity, and therefore its oscillatory movement is limited to a very small angle, and the shortening of the horizontal extension of the rod, on account of this oscillation, may be neglected. Hence the deviation of the valve from its neutral position is equal at any time to the distance of the centre of the disc from the vertical axis.

Before proceeding any further I desire to elucidate a geometrical proposition, which will be necessary for the deduction of the theory of the diagram. If A B, Fig. 3, is a horizontal line intersecting the circle A B C D in A and B, and if A C is a diameter of the same circle, which is a line going through its center, then C is vertically above B. Geometry furnishes the proof by the known proposition that the angle in the semicircle is a right one.

FIG 3.



Returning to Fig. 2, it follows that if a circle is drawn, the diameter of which is the line O C, which represents the excentricity, it will always intersect the horizontal axis OH in a point, D, which is the horizontal projection of the center, C′, no matter whatever position the shaft may occupy, and its distance from O is equal to the deviation of the valve. If the whole diagram except the horizontal axis is rotated in the same direction in which the main shaft of the engine rotates, this point of intersection imitates perfectly the motion of the slide-valve. To find the relative position of the valve for any given angle of the crank, we need only turn the diagram till $O\,A_0$ occupies this position, and we have in the chord $O\,D_0$ the required distance. It would, however, on a drawing-board be very tedious to revolve the whole diagram, and to draw it in different positions while the horizontal line remains stationary. But we attain the same results when, instead of turning the diagram in the positive direction, we turn line O H in the opposite or negative one, through the same angle. We can leave the main characters of the diagram stationary, and need rotate only one line on the center of the diagram. But it is inconvenient to have this motion proceeding in the opposite direction to that of the crank. Nothing is easier, however, than to overcome, also, this difficulty, by simply inverting the diagram, and reproduce it as shown in Fig. 4. For the given angle of the crank, $O\,A_0$, we had, according to the first form of the diagram, $O\,D_0$ (Fig. 2); in the second $O\,D'^{o}$, and in the third form O D (Fig. 4), representing the deviation of the valve. This last diagram is that at which Prof. Zeuner arrived by profound calculations. A line drawn through the center, O, at the angle of the crank, gives instantly the corresponding deviation of the valve, by the length of the chord formed in the valve circle. If this chord is cut out of the negative prolongation of the center-line of the crank, for instance, when the crank is at $O\,A'_0$, then is the deviation of the valve negative. As it were, the two ports changed their functions, and the piston moves in the opposite direction under the same conditions. From this it appears that for directly opposite positions of the crank, the deviations of the valve are equal but reversed.

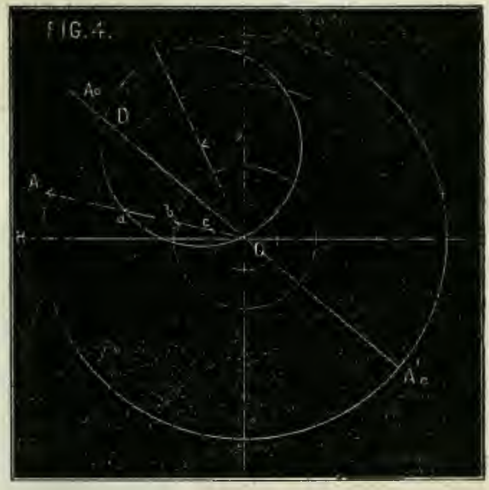


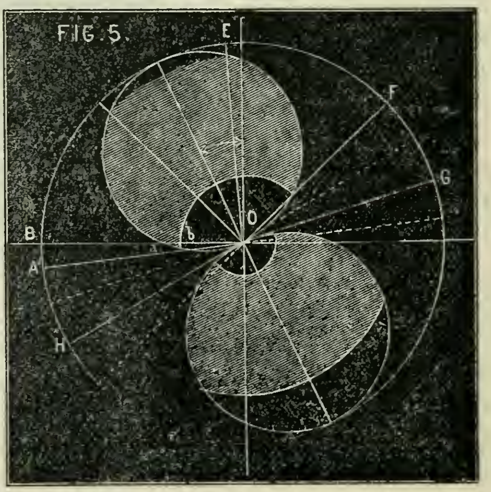
FIG. 4.

The excess over 90° of the angle formed in horizontal engines between the excentric and the crank is called the angular advance, and can, by the following proceeding, easily be determined for any engine. Set the main shaft until the excentric is at a right angle, or, what is the same, until the slide-valve is in the middle of its stroke, and mark the position. Then turn in the positive direction till the crank arrives at its dead point. The angle of this motion is the required angular advance. The diagram should in any case be constructed as though it was intended for a horizontal engine with an equal angular advance, in order to obtain for all engines such diagrams whose general characteristics are uniform.

Since we can by this method find the position of the valve for any angle of the crank, we can easily find the widths of the openings formed for the passage of steam, by drawing two circles whose radii equal the outer and the inner lap. By their aid we can at once subtract from the diverse deviations the respective laps. So is, for instance, for the crank position O A the deviation equal to O *a*, and therefore the port for admitted steam is open as far as *a b*, and that for exhaust as far as *a c*. The outer circles have a respective distance from the two lap-circles equal to the width of the ports, and indicate the angle of motion during which the ports are fully opened, but they are evidently of inferior importance.

To separate the action of admission and of the exhaust of steam, it is advisable to draw a second circle opposite to the first one, as shown in Fig. 5, and to devote one to the admission and the other to the exhaust of steam. This measure can be justified, because the deviations are equal for opposite positions of the crank, but more so, because the same port which will be opened for admission by a positive deviation, will be opened for exhaust when the deviation is negative, and *vice versa*. Following by the diagram the distribution of steam for one side of the cylinder, or for one port, we find that at the posi-

FIG. 5.



tion O A the rotating radius enters into the upper figure which represents the admission of steam, the inner circle having a radius equal to the outer lap. This indicates that at this position of the crank the admission of steam will commence, for the deviation, the chord in the valve-circle, is now equal to the outer lap, as the radius of the lap-circle. When the crank reaches the dead point, B, the port will be opened to an extent equal to *a b*, which is called the lead. Angle A O B is called the lead angle. As the rotation of the main-shaft continues, the width of the formed opening for admission of steam will increase successively till at D the port is fully opened, as its distance from its neutral position equals the sum of the outer lap and the port width. From this time to the time it passes the radius O E the deviation of the valve is greater than necessary to open the port entirely. When the crank arrives at F the radius leaves the upper figure of the diagram. Hence the admission of steam will be interrupted and expansion will commence, and last till the rotating radius enters the lower figure (designated for exhaust, as the radius of the inner circle equals the inner lap) which takes place at G. From there till to the exit of the radius from this figure, at H, the considered side of the cylinder is connected with the exhaust-canal. The steam which after the cut off of the exhaust at H is retained in the cylinder, will be compressed until at A the port is again open for the admission of full steam to start the next stroke. The action on the other side of the piston is similar, and may be examined by following the same course with the negative prolongation of the crank.

Till now we constructed the diagram when the excentricity, the angular advance and the laps were given, and inquired for lead, lead-angle, cut-off-angle and steam-compression. But after knowing the features of the diagram, it can equally well be constructed when excentricity, lead-angle, cut-off-angle and the beginning of compression are given, and the diagram will answer our inquiries on angular advance and inner and outer lap, and thus will be adapted for the construction of new engines.

It is, however, not my intention to explain here all the possible applications of this diagram, as the time is entirely too limited, but the said may suffice to show the logic of the diagram and the manner in which it may be used.

Professor Zeuner used this diagram by the aid of high mathematics for the investigation and construction of the more complicated valve-motions, for the different link-motions and for Meyer's valve with adjustable cut-off plates. The same diagram may also be used in an elementary way for the attainment of the same purpose.

I hope that this new deduction of the theory of the diagram may tend to make the use of this geometrical method more popular among the engine-builders.

BRIDGE-BUILDING CONSIDERED NORMALLY.

By John W. Murphy.

Darwin says we are a race that has descended from a long line of magnificent Apes. Whether I agree with Darwin or not will make no difference in the subject I propose to discuss. I know that the first bridge-builders that were of kin to humanity were the monkey race. Travellers who have been through the wilds of Africa, South America and portions of India tell us how the monkey is a bridge-builder. The traveller has frequently described how he has seen a convoy of monkeys making the attempt to cross a stream, and succeeding by a process which he describes in this wise: The leading monkey climbs a tree as close to the shore as he can make choice of, holding by his forearms to the limb of the tree. He gives opportunity to each succeeding monkey to entwine himself with his prehensile tail, until one after the other they have become so attached, head and tail (the height of the tree being equal to the width of the stream); that the lower monkey, starting forward from the ground, by a pendulum movement swings himself to the opposite side of the stream. He then climbs the nearest tree, and when he has gained the height of the first monkey it will be easy to understand that there will be formed a catenary curve of monkeys from tree to tree across the stream. On this curve the youthful monkeys, the comparatively infantile monkeys and the aged monkeys cross over in perfect safety, and no monkey, either youthful, infantile or aged, wets his feet in the water in crossing.

Now let us see how our catenary bridge is removed when its work is done. The first monkey, by a signal from the other side of the stream, lets go his hold of the limb and swings gracefully to the other side. Now, if Darwin be correct and we *are* descendants of a race of monkeys, then it must be truthfully said that our ancestors have given us the best thoughts and principles of bridge construction.

There is no doubt that the suspension curve, where the material acts by tension, is the most *economic* form, the *safest* form, and the most *artistic* form for the support of moving or stationary bodies over space.

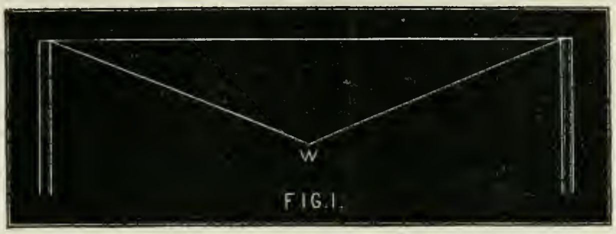


FIG. I.

The Peruvian, with his grass ropes, throws across the gorges of the Andes a primitive bridge, which is no more nor less than the monkey bridge just described, with this difference, that the monkey uses his own *body* to make the chain, while the *Peruvian* uses long grass from the Pampas. Another difference is that the monkey uses but one rope or cable, while the Peruvian uses two. See how easy it is to do as the Peruvian does. We have only to take the material at our hands, make a chain, connect it from point to point, from shore to shore, put some plank upon the two cables that lie side by side, at at any practicable distance apart, and we can make a bridge that we can walk over, if we descend from the summit of the abutment down to the bottom of the deflection of the catenary curve of our rope.

It is plain that, if our ropes are reliable, we can erect staunchions upon them at practicable distances apart, and that we can manage and truss these staunchions so that we may be enabled to construct a roadway on a horizontal line, notwithstanding that this roadway is dependent upon the catenary curve that bellies below it.

Our ancestors (according to Darwin) have therefore given us a magnificent thought. Charles Ellett and John A. Roebling have copied this principle in their great forms of construction, such as the bridge at Niagara Falls, the largest span for railroad purposes in the world —810 feet from shore to shore; the bridge at Cincinnati, the central span of 1110 feet, with two co-ordinate spans of 500 feet each; also the bridge at Fairmount, 342 feet span, designed by Charles Ellett, the first suspension bridge built in the United States.

If 1 could cast aside all the prejudices of the engineering fraternity regarding bridges, I would build them on the same principle that the monkey builds his.

I am free to say that Whipple, Linville and Murphy are all wrong in the principles they evolve in the construction of bridges. While their works show skill and aptitude in the sustainance of bodies moving and stationary over space, I declare that the suspension form is the only *true* form for *any* structure that relies for the conserver of weights that are carried or impinged upon it.

In 1853 I erected a bridge across the Delaware river at Easton, Pa. It was obligatory by my contract that I should execute this work during the spring and summer months. I found that the rafts that came floating down the river made it impossible for me to erect this bridge in the ordinary manner, that is to say, by placing trestles or false works in the stream, upon which the superstructure would ordinarily be erected. I therefore devised the following plan:

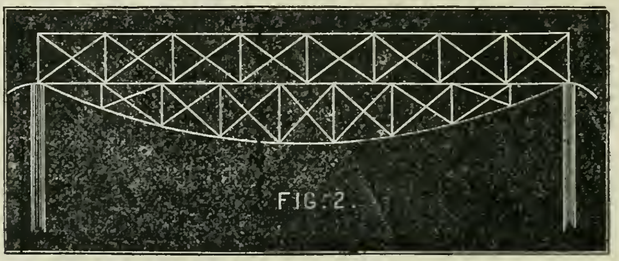


FIG. 2.

I took some wire ropes and suspended them from pier to pier, and placed staunchions upon them, braced them in the manner which will be understood from the drawing, and made a temporary bridge, upon which I erected the main superstructure.

I never will forget the pleasure it afforded me, in the erection of this work, to see the rafts passing freely underneath, and the feeling of security that I had in devising a plan by which I was enabled to erect this bridge without danger to myself, to my men, or to the raftsmen, who were obliged to float upon the high currents of the Delaware, and of course liable to injury to themselves or to my workmen.

Bridge construction, it seems to me, must ultimately come to the natural suspension curve. It is a natural curve. It is as though we were to take a rope or cable and swing it across the space to be spanned. If we examine into the lines of the curve formed by this cable when stretched across such space, we will discover that it hangs in obeyance to the law provided by lines resolved into three forms:

First. Resistance to gravity.

Second. The diagonal value due to that resistance over space.

Third. The horizontal component of these two values, which make the elements of stable equilibrium.

To take this principle and construct mechanically a stable and comparatively permanent structure, demands that we should understand most thoroughly the value of three nodal points of the curve.

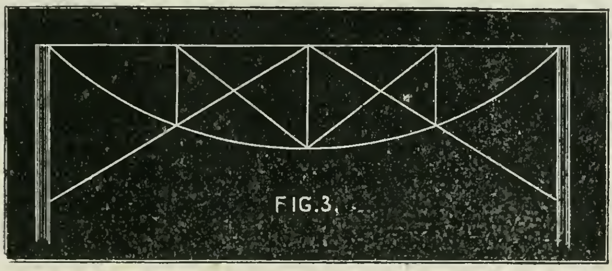


FIG. 3.

I have said that there is one positive line, resistance to which must be provided against, and that is the line in the direction of gravity. The other is the diagonal, which is represented by the curve of our cable.

Material in the direction of gravity in a suspension bridge will be represented by the suspenders that hang from the cable, they supporting the roadway. The one representing diagonal and the other vertical forces, it follows that we have but one force to provide for, viz., the horizontal.

Material proportionate to the value of the strains in the direction of the three forces named must be employed.

Strains upon a suspension bridge are widely different from the strains upon rectangular forms of trusses.

A body supported over space by two lines acting by tension, requires no lateral bracing to hold it in equilibrium from side swinging, provided that care is taken that the width of the bridge at the towers is greater than the width at the centre of the roadway.

The suspension bridge at Fairmount is illustrative of this resistance to side motion ; it having, if I remember right, some fifteen feet greater width between cables at the top of the towers than at the centre of the bridge.

The suspension bridge at Fairmount has no lateral bracing in it, and relies for its resistance to a side swinging motion, to the splay of the cables at the towers, and the compression or tightening of the curve at the centre of the bridge.

If we use the suspension principle in contradistinction to the direct arch, and all the rectangular systems of truss framing, we have at least *one* advantage, that the lateral bracing, both at top and bottom, may in a great degree be dispensed with.

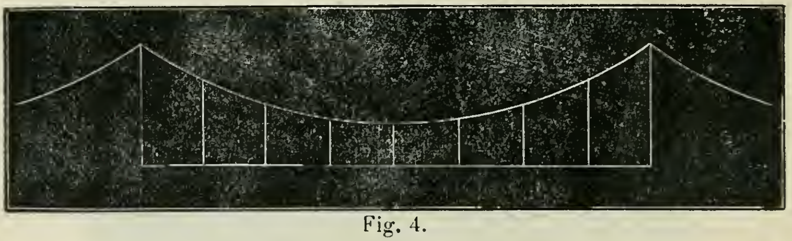


Fig. 4.

When I have turned my suspension bridge upside down, it requires a new order of material to hold in line this arch.

The rectangular truss, in all its forms, involves material acting by thrust, and any form of construction which shall dispense with material acting by thrust is the best form, for this reason, material acting by tension depends for its value only upon the section.

Material acting by thrust depends for its value not only upon the the section but it also depends upon the diameter, if it be a column of any form that may be devised. A No. 10 wire of 10,000 feet long, if sustained in a horizontal line, will maintain a strain, acting by tension, of 1400 pounds; while the same wire, acting by compression, will not sustain a single pound.

In all rectangular forms of bridge construction thrust values exist. The top chord must be kept in line, to resist horizontal strain, in two ways:

First. In and of itself.

Second. By lateral bracing, in order that it maintain itself like a pillar or column.

It follows that when that form of construction that demands the majority of its parts to act by thrust, as is the case of the rectangular bridge, that there are faulty principles in the construction of bridges, *per se*.

In order that material shall resist a thrust strain, it is necessary that three conditions shall be fulfilled:

First. Quantity of material; in other words, cross section.

Second. Diameter; and

Third. That the length of the section shall have some definite relation to the diameter, and the quantity of the material in the cross section thereof.

Now, since parts acting by thrust must have a value equal to the cube of their diameters, directly and inversely as the square of their lengths, it follows that, in all rectangular forms of bridge construction, when that form of construction that demands the majority of its parts shall act by thrust, as is the case of the rectangular bridge —it follows that there are faulty principles in the construction of bridges *per se.*

That form of structure that shall best sustain, support and maintain bodies moving or stationary over space, should be such an one as will have the least amount of material acting by thrust.

If we examine any of the suspension forms, we will find that the primary condition is the hitching fast of a cable into the ground, the anchorage of which serves the part of our horizontal strains.

By making fast our cable into the solid masonry and into the earth itself, we do away in the suspension bridge with all horizontal values except those that are due to vibration.

The objection heretofore existing against suspension forms has been that under variable loads they undulate.

It has been found that where long spans have been constructed, from the great weight of the superstructure, bodies of lighter weight than the superstructure, have produced no undulations destructive or injurious to the superstructure.

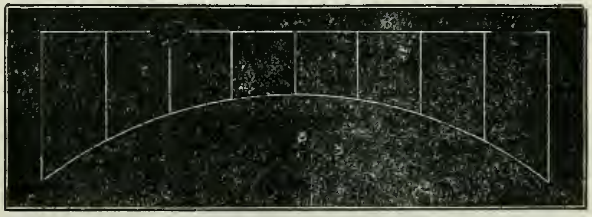


Fig. 5.

A bridge can be constructed on the suspension principle that shall fulfil all the conditions of stability, freedom from vibrations, and absolute integrity as to strength.

It is not necessary, in the practical construction of a bridge based upon a suspension principle, to consider the suspension curve that of the catenary; indeed, it is better to consider the curve as consisting of a series of straight lines from nodal point to nodal point, in fact, a funicular polygon, of as many sides as there are points to be supported.

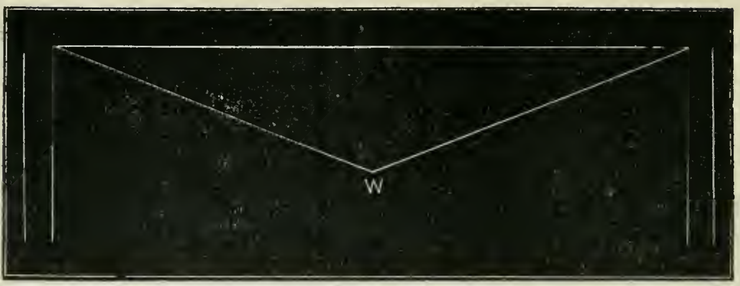


Fig. 6.

Suppose, for the sake of illustration, that we begin with a bridge that shall have but one weight suspended over space; the

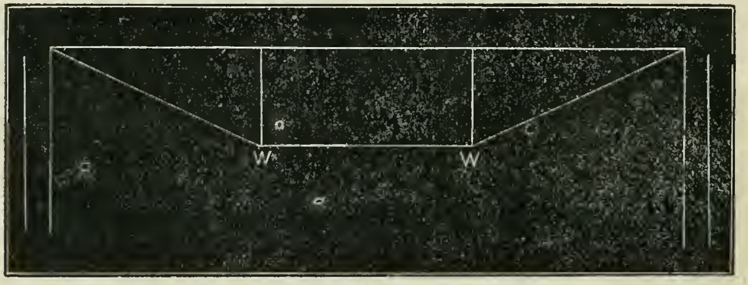


Fig. 7.

weight, W, to be suspended by two chord lines from A to B. Suppose, again, that we have the same chord line supporting two weights, W and W′, dividing the space into what we would call three

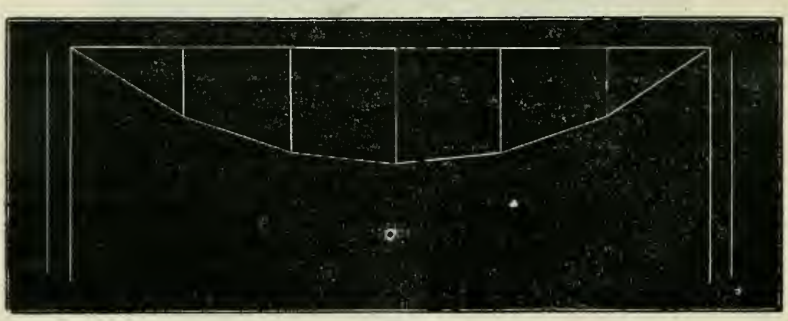


Fig. 8.

panels. We might go forward practically and divide the space between our abutments, as will be seen, into a large number of panels. If we do, the greater the number of panels the greater will be the number of nodal points, and the greater the number of *nodal points* the more closely will our suspension line approximate to the curve of the true catenary.

In the determination of what is requisite for the support of moving loads, it must be understood that if these loads are to be sustained *upon* a flexible cable or chain, or suspended *from* a flexible cable or chain, material must be used which shall act in the direction of tension.

The motive of this paper being to show that the suspension bridge, in any form that it can be constructed, demands *less* material in the lines of thrust strains than any other form, it will be our business to examine how *much* of the suspension bridge acts by thrust.

It will be plainly seen that the main supporting part of a suspension bridge is the cable or chain acting by tension, and that all parts that are to be supplied to resist undulations must act by thrust.

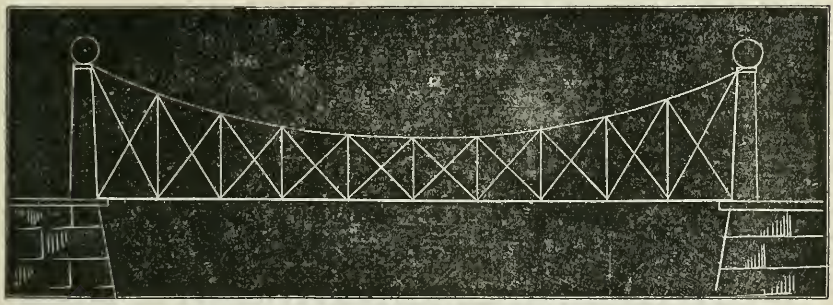


Fig. 9.

Suppose, in the above diagram (Fig. 3), that weights are supported on three nodal points, and that one of these weights is greater than either of the other two; it will be clear that our suspension cable will deflect in the direction of the greater weight and rise in the direction of the lesser weight. It is plain that the nodal points must be placed in equilibrium by material in the direction of a line forming the side of a triangle, which shall satisfy the conditions of equilibrium.

Now, suppose *this* case: a bridge divided into *three* panels (Fig. 3), weights hung upon a chord essentially at *two* nodal points. It is easy to see how we can fasten a chord line from a nodal point on the right to the abutment, and the nodal point to the *left* to the abutment, and thus secure an absolute stability and equilibrium of the nodal points at which places the weights act.

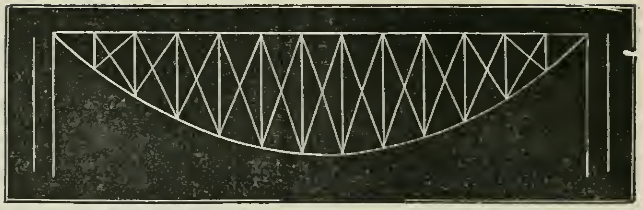


Fig. 10.

If we increase the number of panels, and consequently the number of nodal points, we will not change the principle that I have already demonstrated.

The suspension curve is the natural form for the construction of *any* bridge. It is that form, when placed mechanically exact, gives to us the very *purity* of theoretic bridge-building. It eliminates horizontal values if the cables be hitched on shore. The principle eliminates, furthermore, all lateral bracing.

Out of the three forces that we are to provide material against—the vertical, the horizontal and the diagonal—the suspension principle eliminates most easily the horizontal value, by means of the anchorage at each shore end of the work. The vertical value represented by the little threads that hang the roadway to the cable.

In truth, the suspension principle leaves us the necessity for only the diagonal value for the sustainment of bodies over space, and that is the cable itself.

In a future paper I propose to discuss the mathematics of the forms which I have described.

SOMETHING NEW CONCERNING THE PHYSICAL PROPERTIES OF STEAM.

By John Lowe, First Assistant Engineer U. S. N.

The volume, temperature, pressure, etc., of steam mutually depend the one upon the other, and vary simultaneously with each other. For example: the volume of one temperature and pressure cannot have the temperature and pressure of another volume; but these relations are strictly defined and are unchangeable.

These relations are well known, and may be found tabulated in Isherwood's works with critical exactness.

They are also expressed in the formula $\frac{Vp}{V'p'}=\frac{1+(t-39).0025}{1+(t'-39).0025}$ equation (1). In which V= volume of steam, (t) its temperature, (p) its pressure.

In the following table, column D contains the volume of steam as found in Isherwood's works, with the corresponding temperatures, pressures, etc., in the other columns, while column E contains the volumes as calculated by equation (1). By comparing the columns D and E, it will be seen that the formula is only approximate, but for our present purposes it is sufficient, although it is to be hoped that the co-efficients will be corrected at some future time.

Absolute pressures per square inch.	Temperature, Fahr.	Thermal units in one lb by weight of steam.	Relative volume of steam, water at 39° being unity. Isherwood.	Relative volume of steam calculated from equation (1)	Internal plus the external work of one lb weight of steam calculated from equation (2).	External work calculated from the equation No. (2).	Differences between temperatures 101·36 and t′.	Newly discovered constant derived from columns G and H.
A	B	C	D	E	F	G	H	I
1	101·36	1112·85	17983·2					
10	193·20	1140·86	2373·	2178·8	21624	795·55	91·84	8·662
20	227·50	1151 46	1219·7	1157·2	29700	1099·0	126·14	8·712
30	250·26	1158·26	826·327	801·36	35036	1296·3	148·90	8·706
40	267·17	1163·42	627·903	617·49	39031	1444·6	165·81	8·706
50	280·89	1167·61	508·292	504·93	42265	1565·0	179·53	8·711
60	292·58	1171·17	428 318	428·42	45024	1668·2	191·22	8·723
70	302·77	1174·28	371·076	372·94	47424	1758·5	201·41	8·730
80	311·86	1177·05	328·086	330·79	49564	1838·1	210·50	8·732
90	320·10	1179·57	294·610	297·64	51505	1906·3	218·74	8·715
100	327·63	1181·86	267·806	270·83	53277	1977·4	226·27	8·739

Let us put H as the total heat in steam. Now, if we compress steam from the pressure $p = 1$ to the pressures $p' = 10 = 20$, etc., as in the table, it has heretofore been supposed that a total work of $(H' - H)\ 772$ foot lbs must be performed. $(H' - H)\ 772$ is equation (2). See column F. This work is divided into internal and external.

We will not now attempt to define internal work; but external work may be defined as that which is exerted, for example, upon the piston of a steam-engine. The formula commonly used by the engineering profession to calculate external work is $E = V\,p\,l\left(\frac{p'}{p}\right)$, equation (3). In which $l\left(\frac{p'}{p}\right)$ signifies the Naperian Logarithm of $\left(\frac{p'}{p}\right)$ and E = the work restored by steam during expansion or stored in compression. This formula possesses the merit of simplicity, and for ordinary purposes perhaps is all sufficient. But since the amount of work stored in compression equals the amount restored in expansion, if we accept this formula as correct we must say $E = V p \, l \left(\frac{p'}{p}\right) = V' p' \, l \left(\frac{p'}{p}\right)$, which is absurd by simple inspection. It will be observed that in this formula there is no consideration of temperature. The introduction of this element makes the formula correct, and

$$E = \left[V p \frac{1 + (t'-39^\circ).0025}{1 + (t-39^\circ).0025}\right] l \left(\frac{p'}{p}\right) =$$

$$V' p' \left[\frac{1 + (t-39).0025}{1 + (t'-39).0025}\right] l \left(\frac{p'}{p}\right) \text{ Equation (4).}$$

By this formula column (G) was calculated, and it is believed an important fact discovered, viz: *That the external work given out by steam in expanding from the temperature* (t') *to the temperature* (t), *bears a constant ratio to that difference, that is, to* (*t'—t*).

Column (H) contains these differences between $t = 101.36$ and $t' = 193 = 227$, etc.

Column (I) contains the constant ratio $\frac{E}{t'-t} = 8.7$, etc. This constant it is believed is now for the first time announced.

This constant is, it will be observed, almost a perfect one, the small differences arising from the imperfections of Equation (1). Because at 60 lbs. pressure the observed and calculated volumes coincide, this constant will eventually be put as 8.723.

We have then discovered a new formula for finding the external work, viz: $E = \gamma (t'-t)\, 8.723$. Equation (5). In which γ = the weight in pounds of steam.

This formula is a rigid one, since as before said, the pressure, volume and other properties of steam vary simultaneously. It expresses all the work that can possibly be obtained from steam by the steam engine.

The difference therefore between this formula and the work actually obtained will be the losses from condensation, etc. These losses will be found to be smaller than generally supposed. As before said, it has heretofore been supposed that the work that should be realized from the steam was $W = (H'-H)\, 772$ foot lbs. But the reasoning of this article if sound proves that only

$$\frac{\gamma\,(H'-H)\,772}{\gamma\,(t'-t)\,8.723} = \frac{\gamma\ .305\,(t'-t)\,772}{\gamma\quad (t'-t)\,8.723} = 26.9,$$ or that only $\frac{1}{27}$th part of the total heat can possibly be realized theoretically.

This article is only preliminary; but the opinion of the writer at present is that the latent heat performs the internal work, while the sensible heat only is available for external work. If this is correct, then that vapor whose latent heat is the smallest, other things equal, would be the best agent for converting heat into work.

THE ICE-GORGE IN THE SCHUYLKILL ABOVE FAIRMOUNT.

By John W. Murphy.

A paper read before the Franklin Institute.

The ice-gorge in the Schuylkill, at Turtle Rock, extending backwards up the stream some seven miles in distance, has attracted a good deal of attention.

The fear of the effect of the sudden disgorge of this enormous mass of ice has given grave apprehension to the citizens of Philadelphia.

The Fairmount Dam is in danger. If it gives way, damage and destruction follows. Market street, Chestnut street and the partially completed South street bridges will be swept out of existence.

There is nothing, therefore, that engineering skill can or has devised that can withstand this terrific gorge if once in motion.

Think for a moment of a field of ice some miles long, seven hundred feet wide and twenty feet deep, moved by a freshet such as would send it crashing its way against every obstruction that impeded its progress!

Now the purpose of this paper is to show that this gorge of ice is in fact the protection to all structures below it.

Ice is gorged under two conditions of the stream; the first condition is when the stream is rising, the other is when the water falls. Persons who are accustomed to look upon the breaking up of ice in the river, and seeing masses of ice moved by a freshet, rarely comprehend the difference between an ice-gorge that may last for a moment, for an hour or for two hours, and then break away by force of a continually rising current, and a gorge of ice that has been stranded upon the bottom of a river, where the freshet runs away from it, and leaves it high and dry.

In the latter case, the first portion of the ice-floe is stopped, and jammed against the shores. The water running from underneath it allows it to sink to the bottom. The ice following after accumulates behind, piling in upon the stranded obstruction in front. The subsidiary water fails in strength to move forward the obstruction and only gives opportunity to make the barrier stronger.

An observation of the ice-gorge above the dam at Fairmount shows us that each cake of ice has been set down to the bottom of the river edgewise. As evidence of it, any one who will glance at the surface of it will see that every stick of wood, débris and logs and all light floating material stand upright, as though an engineering party had been driving stakes to make a topographical survey of the territory.

A gorge of ice is always an evidence of a falling stream, in fact it may almost be said a season of drought (low water).

Consequently, before a gorge can be raised, and moved to be destructive to structures below it, there must be a volume of water poured into the stream at least three times greater than the initial freshet that caused the gorge.

If ice weighs 58 pounds and water $62\frac{1}{2}$ pounds to the cubic foot, it will be clear that the difference in flotation will be as 58 is to $62\frac{1}{2}$; in other words, one-sixth in round numbers will be out of water and five-sixths will be submerged.

Now, where a freshet occurs and carries with it a mass of ice five-sixths of which is under water and one-sixth above, whatever be the thickness of the ice, it carries with it elements of great destruction; because the specific gravity of ice is so near to that of water, that when it has great thickness and velocity it acts against any obstruction like a projectile.

An ice-gorge and an ice freshet are widely different, for in the case of the ice freshet the horizontal mass, whatever may be its thickness, is raised from its normal condition and moved forward by the flood.

Referring, then, to our thought, that five-sixths of the ice is below the surface of the water, and, if it be in a condition of flotation, it will require a freshet of 16 feet, measured on the dam at Fairmount, to move the gorge bodily.

I therefore conclude that no danger may be apprehended below any gorge similarly situated as the one above the dam at Fairmount.

Chemistry, Physics, Technology, etc.

STATISTICS OF COAL.

Compiled from the "COAL-REGIONS OF AMERICA; their topography, geology, and development. With a colored geological map of Pennsylvania, a railroad map of all the coal-regions, and numerous other maps and illustrations. By JAMES MACFARLANE, A.M."

I. IN FOREIGN COUNTRIES.

A comparison of our trade with that of our neighbors is always instructive. The largest production of coal in the world is that of Great Britain, which is more than three times that of the United States, and more than all other countries in Europe together. A brief account of it may be useful, now that it is supposed to have attained its maximum, while ours has scarcely passed its infancy.

The following are the official statistics of the coal mined in the United Kingdom of Great Britain:

Years.	Tons mined.	Annual Increase.	Annual Decrease.	Home Consumpt'n.	Tons exported.
1854....	64,661,401	....	....	60,351,146	4,309,255
1855....	64,453,070	....	208,322	59,476,168	4,976,902
1856....	66,645,450	2,192,371	....	60,765,671	5,879,779
1857....	65,394,707	....	1,250,743	58,656,959	6,737,718
1858....	65,008,649	....	386,058	58,479,166	6,529,483
1859....	71,979,765	6,971,116	....	64,972,816	7,006 949
1860....	84,042,698	6,062,933	....	76,720,866	7,321,832
1861....	86,039,214	1,996,516	....	78,184,099	7,855,115
1862....	81,638,338	....	4,400,876	73,336,486	8,301,852
1863....	86,292,215	4,653,877	....	78,017,003	8,275.212
1864....	92,787,873	6,495,658	....	83,977,965	8,809,908
1865....	98,150,587	5,362,714	....	88,980,110	9,170,477
1866....	101,630,544	3,479,957	....	91,676,832	9,953,712
1867....	104,500,480	2,869,936	....	94,084,702	10,415,778
1868....	103,141,157	....	1,359,323	92,303,353	10,837,804
1869....	107,427,557	4,286,400	....	96,839,132	10,588,425
1870....	110,431,192	3,003,635	....	99,926,920	11,501,272
1871....	117,352,028	6,920,936	....	104,802,152	12,549,874
1872....	....	....	....	. ...	13,211,961

It is remarkable that there is no authentic account of the quantity of coal mined in Great Britain previous to the year 1854. The first report of the "Mineral Statistics in the United Kingdom," giving with all possible exactness the quantity of coal raised, as obtained by direct application to the coal-owners, was published in July, 1855, and annually since that period a similar detailed report has been issued. The following is an estimate, made from the best data obtainable, by Mr. Robert Hunt, the chief of the Mining Record Office, of the United Kingdom, of all the coal mined in Great Britain since coal was first used in the country:

Mined in the three centuries before 1800	850,000,000
Mined from 1800 to 1853	2,000,000,000
Mined from 1854 to 1870	1,454,224,897
Total coal mined in Great Britain	4,304,224,897

The following are the uses made of the coal mined in 1869:

Used in iron manufactures	32,446,605
General manufacturing, steam-power, etc	25,327,213
Metallurgies, other than iron	859,231
Mines and collieries	7,225,423
Gas and water-works	7,811,980
Steamships	3,277,562
On railways	2,027,500
Domestic consumption	18,481,527
Miscellaneous	195,045
Exported	9,775,470
Total production in 1869	107,427,557

Among the notable points in the above statement are the very large proportion of the coal used in the manufacture of iron, thirty-two and a half million tons, and the small quantity used on railroads, being only two million tons. In looking forward to our probable future coal-trade, it is evident that our railroads will soon furnish a large, perhaps the largest item in the account of our consumption of coal, instead of one of the smallest, as in England. The use of wood in locomotive engines is only temporary. So large is the consumption of fuel in these machines, that our forests go down before them. On the New York Central Hudson River Railroad each engine consumes seven hundred and fifty tons of coal per annum. On roads with a lighter traffic a less quantity may be used, but it cannot be questioned that the consumption of coal in this manner will very soon amount to many million tons. The use of coal for domestic purposes in this country will very much exceed that of Great Britain in proportion to the population, owing both to the greater severity of the climate, and the more equal distribution of property, which enables our whole people to indulge in the free use of the best fuel. The manufacture of iron is vastly on the increase here, as well as manufacturing generally, both of which have been lately much stimulated by the increased price of coal, and cost of labor of all kinds, in England.

The exportation of coal is a branch of the trade which has scarcely begun in America, and which is destined at an early day to absorb millions of tons of our production. Our beautiful anthracite, the finest domestic fuel in the world, only needs to be known and used, to become one of the luxuries which the wealthy abroad will require of Pennsylvania.

There is the same gradation in the coal-fields of Great Britain as in Pennsylvania. The type of perfection in gas-coal is the Scotch Cannel. The quantity of gas produced decreases constantly in going southward, through the Lancashire, Yorkshire, New Castle, and Staffordshire basins successively. Farther south than the last, the coals run through several varieties of semi-bituminous into the anthracite of South Wales and Ireland, and then into the worthless culm of Devonshire. It is estimated that there are in Great Britain seventy varieties of coal.

The most important and productive of the coal-fields of England is the Durham and Northumberland basin near Newcastle. It is 50 miles long, from six to 24 miles wide, and produces about 24 per cent. of the coal mined in England. In this basin are 16 seams of coal more than 18 inches thick, six of them being more than three feet, and ten of them less than three feet. The two most important beds, the High Main and the Low Main, are each of a thickness of six feet, with a layer of slate or poor coal in each. In England, six feet in thickness of coal is a good bed, and from one to two yards is a common size. This north-of-England region has been for a long time the principal source of the supply of English coal.

The Staffordshire and Worcestershire coal-field is 21 miles long, and its mean breadth is between seven and eight miles. The Dudley coal, in South Staffordshire, is of limited extent, but the principal bed of coal is 30 feet thick, and varies from 24 to 36 feet, which is a very extraordinary thickness; and there are five other good beds, measuring 4, 4, 8, 7, and 12 feet, the whole thickness of coal being 65 feet. Staffordshire and Worcestershire produce about 11 per cent. of the whole product of the United Kingdom. North Staffordshire, called the Potteries, has 40 seams of coal, with a total thickness of 140 feet of coal, of which 22 are large workable beds measuring in all 94 feet. Yorkshire has 16 seams of coal, with a total thickness of 45 feet, of which the best bed is five or six feet. Leicestershire has ten seams of a workable size, with 45 feet in all of coal. The Cumberland coal-field has three workable seams. Derbyshire produces the valuable splint-coal.

Scotland produces 13 per cent. of the coal of the United Kingdom. The great coal-field of Scotland has an extreme length of 94 miles, with an average breadth of 25 miles, and a workable surface of somewhere between 1,450 and 1,750 square miles. In Lanarkshire there are 20 to 30 beds of coal. Clyde has 84 coal-beds; Johnstone has 10 coal-beds—in all 100 feet of coal. The Midlothian has 24 seams, measuring 94 feet. East Lothian has 50 to 60 coal-beds, over one foot thick, in all 188 feet, the thickest being 13 feet. Kilmarnock produces anthracite. Basin No. 34, south of Ayrshire, has 51 feet of coal; and in the Clackman, in Fifeshire, there are 142 coal-seams. In North Wales the coal is bituminous; there are seven beds in all, from 27 to 30 feet thick, the largest being from six to seven feet. The coal-field of South Wales is 54 miles from east to west, and 18 miles in width. The coal-producing rocks are 10,000 feet thick, and a full section shows 25 workable seams above two feet thick, making in all 84 feet of workable coal. Ireland has about 70 collieries, of which 30 are working on old pillars on a small scale, only producing, in all, 165,750 tons in 1871. England, Scotland and Wales had 2,730 collieries in 1871. From the following statement it appears there is but little variation, from year to year, in the relative quantity of coal produced in the several districts:

Summary of the Quantities of Coal produced in each Coal District in the United Kingdom, as officially reported.

DISTRICTS.	1865.	1867.	1869.	Average for ten Years, 1860—1869.
Durham and Northumberland	25,033,000	24,867,000	25,765,000	22,741,000
Cumberland	1,431,000	1,513,000	1,411,000	1,369,000
Yorkshire	9,355,000	9,844,000	10,830,000	9,861,000
Derbyshire	4,596,000	4,551,000	5,460,000	5,756,000
Nottinghamshire	1,095,000	1,575,000	1,575,000	
Leicestershire	965,000	1,150,000	651,000	810,000
Warwickshire	889,000	881,000	586,000	704,000
Staffordshire and Worcestershire	12,201,000	12,527,000	12,669,000	10,374,000
Lancashire	11,965,000	12,841,000	13,996,000	12,047,000
Cheshire	880,000	935,000	957,000	856,000
Shropshire	1,135,000	1,558,000	1,393,000	1,181,000
Gloucester, Somerset and Devonshire	1,875,000	1,975,000	1,980,000	2,735,000
Monmouthshire	4,125,000	4,569,000	4,275,000	3,352,000
South Wales	7,912,000	9,092,000	9,180,000	7,808,000
North Wales	1,983,000	2,371,000	2,155,000	1,997,000
Scotland	12,650,000	14,126,000	14,417,000	12,508,000
Ireland	124,000	125,000	128,000	125,000
Total	98,151,000	104,500,000	107,428,000	93,925,000

In the year 1866 some degree of public anxiety was awakened in England on the subject of the permanence of their coal supply. The scientific journals directed attention to the calculations of Prof. Jevons, and the matter was discussed in Parliament. In June of that year a royal commission was appointed to inquire into the several matters relating to coal in the United Kingdom. After five years of investigation at great expense, with the advantage of paid assistants, and with every facility afforded them for collecting materials, their report was completed in July, 1871, forming three large volumes, in all 1,250 double-column pages, royal quarto size.

"The subjects intrusted to the five committees were: the possible depth of working, waste in combustion, waste in working, the probability of finding coal under the Permian, New Red Sandstone, and other superincumbent strata, and mineral statistics respectively.

"The investigation to determine the maximum depth to which it would be possible to work coal has not been conclusive, but the commissioners consider, from the evidence before them, that it might fairly be assumed that a depth of at least 4,000 feet might be reached. This acknowledgment must give general satisfaction; for, at present, there are only about two mines that have reached one-half of that depth, and, from the experience gained in those, it appears that the high temperature is not in many cases permanent, and is frequently much modified by accidental circumstances. The temperature of the earth is constant at a depth of about 50 feet, and at that depth the temperature is 50° Fahr. The rate of increase in the coal districts is generally about 1° Fahr. for every 60 feet of depth. The heating process is most rapid at first, when the difference of temperature between the air and the strata is greatest, and gradually diminishes as the length of the passage is extended, never ceasing until complete assimilation of temperature. The air takes up the heat much more rapidly in pillar and stall working than in long-wall. The absorption of heat from the strata, by the circulation of the air, gradually lowers the temperature of a mine.

"The labors of Committee C were directed to the inquiry whether there is reason to believe that coal is wasted by bad working, or by carelessness. It seems that the extension of the long-wall system has diminished waste, but much is still lost by bad working and carelessness—a very considerable amount in proportion to that which is actually used. Under favorable systems of working, the loss is about

10 per cent., while, in a very large number of instances, the ordinary waste and loss amounts to 40 per cent.

"With regard to the quantity of coal in known coal-fields, it is estimated that within depths not exceeding 4,000 feet, and after making the necessary deductions, there are (including upward of 130,000,000 tons in Ireland) 90,207,285,398 statute tons; while below 4,000 feet there are 7,320,840,722 tons, making 97,528,126,120 tons in all, and, in the estimate, no consideration has been taken of any bed of coal less than one foot in thickness. To this must be added a further quantity of 56,273,000,000 tons for the probable amount of coal under Permian and other overlying formations at depths of less than 4,000 feet, and deducting 40 per cent. for contingencies, giving an aggregate of 146,480,000,000 tons. Estimating a gradual increase in the population, and that the consumption per head of population will attain its maximum at the end of the present century, a total consumption is shown of 146,730,000,000 tons in 360 years, so that about Christmas, 2231, we shall have to look for our supply of coal from the sub-Permian deposits, at a depth of below 4,000 feet. The commissioners admit that every hypothesis must be purely speculative, but that if the present rate of increase in the consumption of coal be indefinitely continued, even in an approximate degree, the progress toward the exhaustion of our coal will be very rapid."

This report has been severely criticised in the *British Quarterly Review* for July, 1872. The writer argues that there is no doubt that the increase of temperature is at least 1° Fahr. for every 55 feet in depth, and there is reason to believe that it follows an accelerating ratio. At Monkwearmouth mines the depth worked is 1,640 feet below the surface, and, in consequence of the high temperature, the men work shorter hours, which involves an increased expenditure. At Rosebridge, the deepest shaft in England, 2,376 feet, the temperature of the earth is 92°. At 2,690 feet the temperature reaches blood-heat (98°), in which continuous exertion is impossible. The limit to which coal can be extracted, before we commence a steady increase of cost, may be taken at 1,700 feet, and the limit of practicable extraction at 1,000 feet lower. No engineer, who has a reputation to lose, would venture to affix his name to a report that would contemplate the economical working of coal-mines at a lower depth than 2,700 feet. From 1,700 to 2,700 feet there must be a steady increase in the cost of working.

As to the quantity of unmined coal, the estimate includes every thing that is black, and that is more than 12 inches in thickness. It also includes the total cube quantity of coal. As to the very large quantity of coal believed to exist in undiscovered beds, the writer declines to regard the probability of its extraction as being at present a serious question. He figures up but 39,000,000,000 tons as the total quantity of available coal, and that, if the present rate of increase of consumption continues, the last ton of this will be extracted Anno Domini 1945.

It is a mathematical certainty that the exhaustion of a definite quantity of material which is consumed at an annually increased rate is only a question of time. But this is really a narrow and imperfect basis on which to solve the question, how long the supply of coal in England will hold out. It is really, he says, the question of the price at which coal can be laid down in an English port—comparing that paid for the produce of their own mines with that paid for the produce of other coal-fields, including freight—that must determine the question of the activity, or the disuse of the English collieries, whatever may be the amount of coal actually underlying the soil at that time. Within the last year (1872), a very large increase in the wages paid for mining labor, and a great advance in the prices of English coals, have taken place. The proverbial absurdity of "carrying coals to Newcastle" may yet be realized.

There are fifty-nine small coal-basins in France, of which the most important are those of the Loire, and those of St.-Etienne, which are the best known and the largest, comprising about 50,000 acres. In this basin are 18 beds of bituminous coal, and in the immediate neighborhood are several smaller basins containing anthracite. The total area of coal in France is probably not less than 2,000 square miles. In 1864, the Government engineers estimated there were 800,000 tons of anthracite coal produced, and of the 12,000,000 of tons, the mean average quantity obtained annually in France, at the present time, about 1,000,000 tons are hard anthracite, and the same quantity of softer anthracite, containing six or seven per cent. of oxygen and hydrogen. The coal-basins of France are on granite or metamorphic rocks, with beds or rather masses of coal of irregular and unequal thickness, sometimes attaining to 40, 60, and 80 feet, and in one or two places 130 feet in thickness, of a local character. Both in their size, and the granite on which they rest, they resemble the coal-basin near Richmond, Virginia.

Production of Coal in France, compiled from the Official Returns in the Report of the Royal Commission.

	Tons of 2,200 pounds.		Tons of 2,200 pounds.		Tons of 2,200 pounds.
1787	211,160	1848	4,017,875	1861	9,125,040
1788	220,982	1849	3,977,344	1862	10,102,116
1789	235,714	1850	4,354,840	1863	10,518,406
1802	829,105	1851	4,404,941	1864	11,046,794
1811	759,878	1852	4,816,306	1865	11,785,714
1816	924,823	1853	5.831,939	1866	11,807,142
1821	1,114,448	1854	6,709,535	1867	12,148,223
1826	1,513.482	1855	7,317,226	1868	12,800,000
1831	1.728 950	1856	7,784,165	1869	
1836	2,789,858	1857	7,755,987	1870	
1841	3,349.303	1858	7,221.267	1871	
1846	4,389,532	1859	7,337,326	1872	
1847	5,065,109	1860	8,155,394		

The Belgian coal-field is one of the most important in Europe, but not the most productive, and occupies two districts, that of Liege, containing 100,000, and that of Hainault, containing 200,000 acres. In each the number of coal-seams is very considerable, but the beds are so thin, and so much disturbed, as to require special modes of working, and they produce various qualities of coal. The small extent of the Belgian coal-field, says L. Simonin, is compensated for by the great number of the coal-seams, and by their numerous and singular zigzag contortions, which have the effect of increasing the quantity in a small, workable surface. All the seams, even to the very thinnest bands, have yielded to the elevating and compressing force, without being fractured, except at certain points; even the sharp bends in the angles having been produced without undergoing fracture. In this respect, the formation resembles our anthracite coal-fields.

The production of 1869 was represented by old Prussia, 23,761,094; Saxony, 2,584,292; Bavaria, 340,571; and the other states of the Zolverein, 88,411; in all, 26,774,368 tons. The coal production of Prussia is larger than that of any other country in Europe. The brown coal included in the above statement is less than one-third of the whole amount.

In Prussia, the coal-measures are said to be 20,000 feet thick, containing 117 seams, in all 294 feet of coal. In another field there are 164 seams, over six inches thick, in all, 338 feet of coal; and of workable seams there are 77 seams with 240 feet of coal in a region 60 miles long by 20 miles wide. Some of the seams are 10, 12, and 14 feet thick, and it is extraordinary that the lowest known seams are bituminous or caking coals, and, the higher they range in the series, the more dry or anthracite do they become. In Hungary, there is a brown coal of a good quality, in beds of the thickness of 50, 70, and even 120 feet.

Production of Coal in Belgium.

	Production.	Exportation.		Production.	Exportation.
1834		660,012	1854	7,947,742	2,625,958
1835		695,586	1855	8,409,330	2,974,349
1836	3,056,464	773,612	1856	8,212,419	2,866,137
1837	3.228,806	789,083	1857	8,383,902	2,887,012
1838	3,260,271	775,534	1858	8,924,714	3,091,316
1839	3.479,161	745,569	1859	9,260,702	3,145,235
1840	9,930,232	779,474	1860	9,609,895	3,450,306
1841	4,027,765	1,015,194	1861	10,057,163	3,379,409
1842	4,140,462	1,014,716	1862	9,758,223	2,840,337
1843	3,982,274	1,086,321	1863	10,160,590	2,839,348
1844	4,445,240	1,245,399	1864	10,959,078	3,264,243
1845	4,919,156	1,543,472	1865	11,629,163	3,503,978
1846	5,037,402	1,355,833	1866	12,546,541	3,971,272
1847	5,664,456	1,827,105	1867	12,544,038	3,564,308
1848	4,862,694	1,460,570	1868	11,755,956	
1849	5,251,843	1,664,973	1869	12,959,704	
1850	5,820,588	1,987,184	1870	13,496,564	
1851	6,233,517	2,057,050	1871	13,671,470	3,186,204
1852	6,795,254	2,103,546	1872		
1853	7,172,687	2,331,595			

Production of Coal and Brown Coal in Prussia (Silesia, Rhenish Provinces, Westphalia, and Saxony, etc.), now Germany.

YEARS.	Tons of Coal and Brown Coal.	YEARS.	Tons of Coal and Brown Coal.	YEARS.	Tons of Coal and Brown Coal.
1837	1,950,919	1863	16,906,707	1868	25,704,758
1857	9,841,220	1864	19,408,982	1869	26,774,368
1858	10,721,323	1865	21,794,705	1870	
1860	12,347,828	1865	21,628,746	1871	
1861	14,133,048	1867	24,738,327	1872	
1862	15,576,278				

In the province of Asturias, in old Castile, in the northern part of Spain, is a coal-field which in length reaches from the frontiers of France to those of Portugal, and in breadth at least eight or ten miles, and probably much more. It is said to contain 60 coal-seams, and other accounts say upward of 100 workable seams of bituminous coal, from 3 feet to 6½ feet, and some of them even 13½ feet thick, of the very best quality of coal, equal to that of Northumberland and Durham. These beds are variously inclined and contorted, often nearly vertical, and even reversed. The coal-fields of Asturias are likely hereafter to be ranked among the most valuable in Europe, but at present the production is small. Reducing their metric quintals to tons of 2,240 lbs., the production in 1864 was 175,595 tons; in 1865, 208,864; in 1866, 177,776 tons; and 550,387 tons in 1869, besides 39,420 tons of lignite.

The great majority of the deposits of coal in Austria are found in the north-west portion of the empire, and the Tertiary deposits do not yield in importance to the more ancient formations. The following tabular statements contain all that would afford much interest to American readers.

Quantities of coal and brown coal produced in each province in 1862, that of Bohemia being the largest, the Austrian centners being reduced to tons of 2,240 lbs.:

PROVINCES.	Tons.	PROVINCES.	Tons.
Lower Austria	132,290	Galicia	120,816
Upper Austria	128,453	Dalmatia	7,886
Styria	490,981	Lombardy	......
Illyria	120,413	Venetia	16,118
Coast-land	13,216	Hungary	561,832
Tyrol	4,832	Bannat	22,169
Bohemia	2,078,183		
Moravia and Silesia	828,594	Total	4,525,783

Production of Coal and Brown Coal in the Austrian States, in Gross Tons.

YEARS.	Tons.	YEARS.	Tons.	YEARS.	Tons.
1823	134,316	1840	469,662	1857	2,493,375
1824	149,280	1841	526,714	1858	2,887,543
1825	153,381	1842	519,825	1859	3,107,028
1826	171,308	1843	516,464	1860	3,476,088
1827	178,341	1844	639,168	1861	4,032,988
1828	171,371	1845	715,979	1862	4,525,783
1829	167,329	1846	793,823	1863	
1830	208,958	1847	827,409	1864	
1831	195,778	1848	No returns.	1865	
1832	212,140	1849	No returns.	1866	
1833	194,288	1850	1,116,998	1867	
1834	235,547	1851	1,354,487	1868	6,199,027
1835	248,792	1852	1,668,475	1869	6,685,112
1836	271,563	1853	1,736,342	1870	
1837	280,886	1854	1,842,252	1871	
1838	332,353	1855	2,084,375	1872	
1839	428,636	1856	2,319,838		

II. IN THE UNITED STATES.

There can be no more deceptive statement made in regard to the American coal-fields, which may be at the same time true, than that of their area only. But the reader, who is presumed to have read the preceding portion of this work, will be thereby enabled to discriminate between good and bad quality, thick and thin seams, their nearness to the surface, and the facilities for mining and transportation to a good market; but especially between good and bad quality. In order that no one may be misled by mere size, the following tabular statement of the areas of the coal-fields in each State is accompanied by another, giving the annual production of each, so as to lead to a more just estimate of their present importance. The State of Kansas contains far more square miles of coal than Pennsylvania; yet the large bed in the little Hazleton Basin, five miles long, and less than one mile wide, is worth more than all the coal in Kansas. The fourth great coal-field, or that in the States of Iowa, Missouri, Nebraska, and Kansas, contains 64,887 square miles of surface, and great as is its importance in that vast, fertile, treeless, prairie country, yet it cannot be compared, in any respect but size, to the first or Alleghany coal-field in the States of Pennsylvania, Ohio, Maryland, West Virginia, Eastern Kentucky, Tennessee and Alabama, containing 58,737 square miles, the coal in the latter being so much better. But, in any view that may be taken, we should be content with our bountiful stores of coal, although it is not all of equally good quality.

Area of the Coal-fields of America, and their Annual Production.

STATES CONTAINING COAL.	Area in square miles.	Tons produced by Census Report, 1866—'70.	Tons produced in 1872. Estimated.
1. Pennsylvania Anthracite...........	472	15,648,437	19,000,000
" Bituminous	12,302	7,800,356	10,442,000
2. Maryland (Big Bed, 23 miles).....	550	2,345,153	2,355,500
3. West Virginia (Taylor, 21,195)..	16,000	608,878	700,000
4. Ohio....................................	10,000	2,527,285	3,000,000
5. East Kentucky	8,983	35,488	40,000
6. Tennessee....	5,100	133,418	200,000
7. Alabama (First Coal-field, 58,737)	5,330	11,000	15,000
8. Michigan (Second Coal-field)......	6,700	28,150	30,000
9. Indiana	6,450	437,870	800,000
10. Illinois............................	36,800	2,624,163	3,000,000
11. W Kentucky (3d Coal-field 47,138)	3,888	115,094	300,000
12. Iowa....................	18,000	263,487	300,000
13. Missouri..............................	26,887	621,930	700,000
14. Nebraska..........................	3,000	1,425	1,500
15. Kansas (4th Coal-field, 64,887)..	17,000	32,938	40,000
16. Arkansas..............................	9,043	....	....
17. Texas	4,500	....	....
18. Virginia..............................	185	61,803	62,000
19. North Carolina.......................	310	....	....
20. Massachusetts, and 21. Rhode Island......... }	500	14,000	14,000
Totals*.	192,000	33,310,905	41,000,000

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* The total area of the 37 United States is 1,950,171 square miles, without the Territories. The coal-area is, therefora, one square mile in ten. The area of the 10 Territories is 995,032 square miles, making an aggregate of 2,915,203 square miles. The area of lignite in the Territories is not known.

THE UTILIZATION OF COAL WASTE.

Description of E. F. Loiseau's Machinery.

The following is a description of the machinery which Mr. Loiseau intends to erect at Nesquehoning for the manufacture of anthracite coal dust, or waste, into "artificial fuel." A model occupying a space of six feet in length, two and a half feet in height and two feet in width, shows the entire process of manufacturing the fuel with great completeness.

The coal dust is dumped on a platform and pushed into the hopper of a stationary cylinder, in which revolves a shaft; to this shaft are fastened six radiating partitions, which divide the interior of the cylinder into six equal spaces; the coal dust fills these spaces, and the rotary motion given to the partitions carries it to an opening below, where it is discharged. A smaller hopper, close to the first one, receives the clay, previously dried and ground; this clay is carried through a smaller cylinder containing also revolving partitions, and is discharged in the same chute as the coal dust with which it mingles.

The space between the partitions of the clay cylinder is calculated to receive and discharge regularly five per cent. of clay, while from the larger cylinders *ninety-five* per cent. of coal dust is discharged. This dividing apparatus is very simple and mathematically correct.

The mixture of coal and clay, while falling under a chain elevator, is sprinkled with milk of lime and is raised in a moist condition, by said elevator, above the hopper of a conveyer in which it is discharged. A screw propeller revolving in this conveyer forces the materials into a mixer, where they are rapidly worked into a plastic mass by seven upright shafts, to each one of which four-teethed arms are fastened by set screws; these arms cross each other in all directions and thoroughly mixes the coal and the clay. By a very ingenious and new device, the shafts can all be removed and replaced, without removing the frame in which they stand.

Through suitable openings at the bottom of the mixer the plastic mass falls along a chute in the pug mill of the compressing machine, and is forced by a series of knives and a propeller fastened to central shaft through an aperture at the bottom between two moulding rollers having on their periphery a series of oval moulds. These rollers, revolving in opposite directions, receive between them, from the pug mill above, the plastic mass in a continuous sheet and moulds it into *egg-shaped* lumps. The lumps are discharged under the rollers on an endless wire-cloth belt, to which motion is imparted by cast-iron balls (represented in the model by beads), these balls secure under the wire-cloth a rope, which strengthens it. The rollers, around which the wire-cloth belt revolves, have concave receivers wherein the balls successively fall, thus forcing the said belt to move forward and to discharge the coal into a hopper placed on top of the drying tunnel.

The feeding of the plastic mass to be compressed can be regulated in three different ways: 1st, by placing the knives inside the pug mill at any required angle. 2d, by increasing or reducing at will the number of revolutions of the shaft to which the knives are fastened, and 3d, by increasing or reducing the size of the aperture at the bottom through which the plastic mass is forced between the moulding rollers. The latter is done by dividing the bottom into two halves meeting obliquely downward and worked separately by a worm screw or by a lever (the model shows a lever to each half). By removing from one another the two halves of the bottom, or by bringing them nearer together, the size of the aperture between them is longitudinally increased or reduced.

The drying tunnel is heated by two fire-places, one at each end. It contains five moving endless wire cloth belts placed over one another, and so disposed that the balls move in a groove under each belt, so that the coal cannot fall from them. These belts revolve in opposite directions around rollers placed at each extremity of the tunnel.

The lumps of compressed coal discharged from the press-carrying belt, fall in the dry-tunnel on the top belt and are carried by it the entire length of said tunnel, where they fall on an apron which guides them to the second belt below; on this belt the coal travels again in the opposite direction the entire length of the tunnel; it is then discharged on another apron, along which it slides on the third belt below, and so on from the third belt to the fourth and from the fourth to the fifth. This last belt carries the coal out of the tunnel and discharges it into the buckets of an elevator by which the coal is raised and discharged on the "waterproofing belt." This belt is guided by balls on each side in an open tank, on the sides of which are grooves describing a curve. This tank is kept filled with the waterproofing compound, supplied from a larger tank near by; the belt has small partitions to prevent the sudden fall of the lumps in the mixture and to rake them out of it; the balls moving in the curved grooves immerse the coal continually in the waterproofing liquid. When coming out of the bath, the liquid in excess on the coal falls in drops through the wire cloth into a gutter placed under it and through a pipe in a suitable vessel.

The waterproof compound used by Mr. Loiseau is rosin or any other gum dissolved in benzine. To evaporate rapidly this benzine, the coal coming out of the bath is discharged into the hopper of a second tunnel of smaller proportions than the drying tunnel, in which there are only three belts placed one above another. A blower forces into this tunnel a strong supply of air, which evaporates the benzine, while the coal is travelling from one belt to the other. From the third and last belt the coal falls through a chute into the coal car standing outside. The end of the chute can be raised to allow time for the removal of a loaded car and the placing under the chute of an empty one.

The motion given to the coal in the tunnel brings only a few lumps in contact with one another, thus giving to all the lumps the full benefit of the heated atmosphere and drying them more rapidly. In Europe the coal is still piled up in cars with perforated sides and bottom and baked in ovens, which requires much time, unnecessary handling and consumes a large amount of fuel.

Mr. Loiseau shows by full-sized models how the balls (represented in the small model by beads), are fastened to the wire-cloth belts and to one or two wire ropes.

From the moment that the coal dust is pushed into the coal hopper, the whole process of manufacturing it into artificial fuel is carried on automatically. The coal dust and the clay are mixed in the required proportions with the milk of lime; these materials are carried, mixed, compressed into lumps, dried, made waterproof, the benzine is evaporated and the coal is loaded on cars ready for market all by machinery. During the entire process the coal is constantly in motion.

The process itself, and the machinery for its application, are the invention of Mr. Loiseau.

For ten months Mr. Loiseau has been experimenting at Nesquehoning with machines erected by another company, and he has been enabled to judge practically of all the difficulties in the way of the manufacture of artificial fuel from anthracite coal dust, and to profit from the failure of others. Mr. Loiseau's work at Nesquehoning, has been under the auspices of the Lehigh Coal and Navigation Company.

ON THE MOLECULAR CHANGES PRODUCED IN IRON BY VARIATIONS OF TEMPERATURE.

By Prof. R. H. Thurston.

(Continued from page 203.)

42. David Kirkaldy, of Glasgow, in December, 1860, while conducting one of the most extended, accurate and well-arranged experimental inquiries into the value of the tenacity of iron and steel that has yet been made,* took occasion to examine the action of frost upon them.

"A bar of Glasgow B, best ¾-inch diameter, was converted into ten bolts, in the ordinary way. Six were exposed all night to intense frost, and tested in the morning with the thermometer at 23° Fahr. The others were kept in a warm place, and carefully protected during testing. Three were tested with gradual, and seven with sudden strains." "When the strain was gradually applied, there was very little difference between the specimens tested in the ordinary condition and the two that were frozen; the former bore 55,717; the latter, 54,385; or 2·1 per cent. less. The difference, under sudden strains is somewhat greater, viz., 3·6 per cent. less when frozen." This iron was of good quality, and Kirkaldy remarks that "had it been of a coarser description, the difference, when frozen, might have been much greater." He concludes† that "the breaking strain is reduced when the iron is frozen; with the strain gradually applied, the difference between a frozen and an unfrozen bolt is lessened as the iron is warmed by the drawing out of the specimen."

Kirkaldy noticed that "The amount of heat developed is considerable when specimen the is suddenly stretched"—an important circumstance which had previously escaped the observation of experimenters.

43. This subject was debated at some length at meetings of the Manchester Literary and Scientific Society, some two years ago, and experiments were described which afforded data of value and interest.

Mr. William Brockbank described his experiments, made for the purpose of determining the effect of cold upon the cohesion of cast-iron. Using a mixture of several irons of quite different qualities (Cleator red hematite, Pontypool and Blaenavon cold blast and Glengarnock hot blast irons, with scrap added), he found a perceptible decrease of strength with decrease of temperature. He noted a similar effect where wrought-iron was used. The experience of well-known ironmasters was adduced in corroboration of these conclusions, the examples being, usually, instances of breakage by *shock*. The conclusion of the experimenter* was that "bar iron, boiler plate, wire billets and rails are most materially weakened by the action of intense cold, losing their toughness, becoming quite brittle under sudden impact, and having their structure changed from fibrous to crystalline."

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* Experiments on Wrought-Iron and Steel; David Kirkaldy, Glasgow, 1863; p. 85.

Ibid., p. 95.

44. Sir William Fairbairn stated the results of his experiments, substantially as has been already given, attributing the more frequent breakage of wheel tyres in cold weather, to which allusion had been made, to unequal strains due to shrinkage, rather than to loss of tenacity.

45. Dr. Joule gave an account of his own experiments, upon a smaller scale, made at temperatures of 12° and 55° Fahr., with weights applied without shock. The result indicated an increase of strength at the lower temperatures, in the proportion of $58\frac{1}{8}$ to $59\frac{5}{6}$, or $2\frac{1}{2}$ per cent. as a mean of twelve experiments. Experiments, 41 in number, in which the breakage was produced by shock, gave the opposite result. These experiments were made upon large steel needles, and upon cast nails. They have been sometimes ridiculed as too insignificant to afford valuable evidence, but, insignificant as they may appear, and roughly made as they undoubtedly were, they are valuable as giving corroborative evidence of the fact which has already been quite proven, that decreasing temperatures, in general, produce increased strength, but decreased elongation and resilience.

He concludes that "Frost does *not* make either iron (cast or wrought) or steel brittle, and accidents arise from the neglect of the companies to submit wheels, axles, and all other parts of their rolling stock to a practical and sufficient test before using them.

46. Mr. Peter Spence gave a description of his experiments upon bars of cast-iron, one-half inch square, placed on supports nine inches apart, and broken by carefully applied and steady pressure.

Six experiments were made at 60°, and six at 0° Fahr. He sums up the evidence thus:

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* Nature, 1871.

"The bars at zero broke with more regularity than at 60°, but, instead of the results confirming the general impression as to cold rendering iron more brittle, they are calculated to substantiate an exactly opposite idea, namely, that reduction of temperature *cœteris paribus*, increases the strength of cast-iron." He found this increase to amount to 3½ per cent. between 60° and 0°.

47. Subsequently, Mr. Spence made a more extended series of experiments.

He obtained 50 bars of cast-iron (of mixed Scotch brands), each three feet long and one-half inch square, cut them into lengths of one foot, and mixed them thoroughly. Seventy pieces were tested at zero, after 48 hours exposure to a freezing mixture of salt and ice, and seventy were tested at 70° Fahr.

The breaking weights of the pieces averaged 430·3 lbs., warm, and 442·8 lbs. at zero, the weight being placed midway between supports nine inches apart.

Mr. Spence finally says:* "I have no hesitation in giving it as an ascertained law, that a specimen of cast-iron, having, at 70° Fahr., a given power of resistance to transverse strain, will, on its temperature being reduced to 0°, have that power increased three per cent."

Mr. Spence notices a circumstance, which occurred in the course of his experiments, which may throw some light upon the molecular constitution of metals and thus, indirectly, upon the subject discussed. A weight of 449 lbs. had been suspended from one of the bars tested, for the space of nearly two minutes; the bar finally broke after a single one lb. weight had been, without the slightest jar, lifted off—so slowly, in fact, that its upward motion was barely perceptible. It may be imagined that the fact is new evidence of the existence of viscosity in even cold iron.

48. The most complete investigation ever made, particularly to determine the effect of changes of temperature in modifying the physical properties of iron and steel, was that of Knuff Styffe, the director of the Royal Technological Institute at Stockholm, Sweden, and supplemented by the experiments of Christer P. Sandberg, who translated the report of Styffe into English.

The work of the first-named engineer was done at the instance of a committee appointed by the King of Sweden. It was commenced by Professor Angstrom, continued by Herr R. Thalen, of the University of Upsala, and by Engineer K. Cronstrand, and it was finally concluded, with the assistance of Cronstrand and Lindell, by Styffe, who wrote out the results of the whole investigation and made the report public.

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* London *Engineering*, 1871; vol. 11, p. 172.

These labors were begun in 1863, and extended over several years.

The conclusions of Styffe were:

"(1). That the absolute strength of iron and steel is not diminished by cold, but that, even at the lowest temperature which ever occurs in Sweden, it is at least as great as at ordinary temperature (about 60° Fahr)."

"(2). That, at temperatures between 212° and 392° Fahr., the absolute strength of steel is nearly the same as at ordinary temperature, but in soft iron, is always greater."

"(3). That neither in steel nor in iron is the extensibility less in severe cold than at ordinary temperature, but that, from 266° to 320° Fahr., it is generally diminished, not to any great extent in steel, but considerably in iron."

"(4). That the limit of elasticity, in both steel and iron, lies higher in severe cold; but that at about 284° Fahr., it is lower, at least in iron, than at ordinary temperatures."

"(5). That the modulus of elasticity in both steel and iron is increased on reduction of temperature, and diminished on elevation of temperature; but that these variations never exceed 0·05 per cent. for a change of temperature of 1·8° Fahr., and, therefore, that such variations, at least for ordinary purposes, are of no special importance."

49. An equally well conducted series of experiments on transverse strength and the flexure of iron and steel led to the following conclusions:

"(1). Iron sustains, at lower temperatures, a greater, and at higher, a smaller load than at the ordinary temperature, before it obtains any perceptible permanent deflections."

"(2). The modulus of elasticity for steel and iron on flexure, may, for practical purposes, and without committing any considerable error, be generally assumed equal to that on traction. It is diminished by permanent deflection, but may be restored by heating, especially if raised to a red heat."

"(3). By hardening steel, its modulus of elasticity is diminished, but this diminution has not, in any of the hardened bars examined, amounted to more than about three per cent."

"(4). The elastic force of iron and steel on flexion, as on traction, is increased on reduction of temperature and diminished on elevation of temperature. The amount of this increase or decrease for a change of temperature equal to 1·8° Fahr. (1° centigrade) does not, however, in general, amount to more than 0·03 per cent., and, apparently, never rises to 0·05 per cent."

50. The experimenter states that "the results of the experiments given above are evidently opposed to the opinion hitherto commonly entertained, viz., that steel and iron become weak or brittle at low temperatures," and gives it as his opinion that the cause of the frequent breakage of rails in cold weather, and of articles made of iron and steel, is unequal expansion and contraction and the rigidity of supports, where, as is the case with rails, frost may very greatly affect them.

51. Sandberg, while admitting the care and the accuracy which distinguished this extensive series of experiments, still doubted whether the reasons just given were the sole reasons why metals should more readily break in cold than in hot weather, and, having obtained the consent of the State Railway Administration, he conducted a series of experiments, in the summer and winter of 1867, at Stockholm, to determine whether, with equal rigidity of supports, iron rails would yield with equal readiness to blows at the two extremes of temperature.

The rails experimented upon were each cut in two halves, and one piece was tested in cold, and the other warm, weather, at temperatures of 10° and 84° Fahr. respectively. The supports at the ends of the rails were granite blocks, placed four feet apart, and resting on the smoothly levelled surface of the granite rock. They were broken by a heavy drop, weighing nine cwt.

Sandberg's conclusions, from 20 experiments, are thus given:

"(1). That, for such iron as is usually employed for rails in the three principal rail making countries (Wales, France and Belgium), the breaking strain, as tested by sudden blows or shocks, is considerably influenced by cold; such iron exhibiting, at 10° Fahr., only from one-third to one-fourth of the strength which it possesses at 84° Fahr."

(2). That the ductility and flexibility of such iron is also much affected by cold; rails broken at 10° Fahr., showing, on an average a permanent deflection of less than one inch, whilst the other halves of the same rails, broken at 84° Fahr., showed a set of more than four inches before fracture."

"(3). That, at summer heat, the strength of Aberdare rails was 20 per cent. greater than that of the Creusot rails; but that, in winter, the latter were 20 per cent. stronger than the former."

Sandberg suggests that this considerable decrease of toughness at low temperatures may be due to the "cold shortness" produced by the presence of phosphorus.

Our knowledge on this point must remain imperfect until similar experiments have been made with iron free from phosphorus.

52. The researches above described constitute the experimental basis of our knowledge of the effect of change of temperature in producing alterations of molecular structure and of strength and resilience in metals.

A few other less elaborate, though instructive, experiments have been made, some of which enlarge our knowledge of molecular physics somewhat, although bearing less directly upon the problem under consideration.

53. Professor W. F. Johnson, in 1844, gave the results of experiments made under the direction of the United States Navy Department, which revealed the fact that the increased strength, at moderately high temperatures, which was noted by the committee of the Franklin Institute, was retained, on cooling, provided that the bars were submitted to powerful tension while heated.

Prof. Johnson reports* that "the average gain of length of bolts of iron treated at the Washington Navy Yard, by this same process, was 5·75 per cent., and the gain of strength 16·64, making, together, the gain of value 22·4 per cent.

"In many instances the experiments made at the Franklin Institute proved the gain of length to exceed 7 per cent. The report to the bureau also confirms what had been previously observed, viz., that the total elongation of a bar of iron, broken in its original cold state, is from two to three times as great as the same force would produce upon it if applied at a temperature of 573°, which force, will, moreover, not break the bar at that temperature."

54. Professor Thompson has indicated† the existence of a resistance to molecular movement, such as has been referred to already, and designated "molecular friction." He calls it "viscosity." The term, thus used, designates a somewhat different property from that

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*Senate Document, No. 1, 1844—5; and American Journal of Science and Arts, 1846, vol. 1, p. 300.

† Civil Engineers' Journal, Vol. 28.

to which the name is generally applied, and which was illustrated by Tresca's experiments, already described, and other similar experiments.

He deduced the following:

(1). That there is a certain internal resistance which is independent of the elastic properties of metals.

(2). That it does not affect the coefficient of elasticity.

55. A singular action has been recently detected by W. H. Johnson,* which may prove instructive in this connection.

Iron was immersed in hydrochloric acid one or more hours, and then tested for elongation and breaking strain. The pieces were then heated, and again tested with the following results:

"(1). That immersion in acid diminishes the breaking strain of iron wire from ½ to 3 per cent., and of steel wire about 4·76 per cent.

"(2). That immersion in acid appears, in some cases, to diminish, and, in others, slightly to augment the elongation of iron wire, and to augment the elongation of steel wire about 30 per cent."

Heat restored to the iron its original toughness.

Pyroligneous and sulphuric acids had the same effect as hydrochloric, in different degrees.

Copper was not affected in this manner.

The cause of this peculiar action remains undetermined. The phenomenon is of interest principally as confirming an inference deducible from other experiments, viz., that, in general, circumstances tending to increase the strength of a metal, by molecular change, also tend to reduce its viscosity and its extensibility, and *vice versa*.

56. The experiments of Mr. Oliver Williams,† in determining the change produced in the character of the fracture of iron by transverse strain, at extreme temperatures, were more evidently pertinent to this subject.

Mr. Williams says, of two specimens of nut iron, cut from different bars, made at Catasauqua, Pennsylvania, "These specimens were first nicked with a cleft on one side only, and then broken under a hammer, at a temperature of about 20° Fahr. At this temperature, both specimens broke off short, showing a clearly defined granular, or steely iron fracture. The pieces were then gradually heated to about 75° Fahr., and then broken, as before, developing a fine, clear, fibrous grain. The two fractures were but four inches apart, and are entirely different."

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* "Iron," April, 1873, p. 452.

† *The Iron Age*, New York, March 13, 1873, p. 16.

57. It has been long known that a granular fracture may be produced by a shock, in iron which appears fibrous when gradually torn apart.

This was fully proven by Kirkaldy.* Mr. Williams was, probably, the first to make the experiment just described, and thus to make a direct comparison of the characteristics of fracture in the same iron at different temperatures.

A fair inference from these experiments is, apparently, that a reduction of temperature increases the polarizing force, decreases the viscosity of the metal, and thus causes its fracture to assume the appearance which characterizes the fracture of substances which are remarkable for their rigidity; while elevation of temperature, increasing viscosity, allows greater extension before fracture, and this greater toughness is evidenced by the sort of fracture characteristic of less brittle materials.

58. Nothing in these experiments affords any indication of the effect of change of temperature, in this instance, upon the strength of the metal. It has, however, been shown that low temperatures increase the strength of metals, and Mr. Williams' experiments are confirmatory of the supposition, of which strong evidence has already been quoted, that it also *decreases* resilience, or the power of resisting blows and heavy shocks.

The experience of every mechanic who has observed the behavior of tools and of metals at different temperatures, also confirms this belief. Tools yield readily to blows, where exposed to severe cold, although not evidently weak under steady strain.

59. It has been remarked (Article 22), that we should anticipate that the effects of change of temperature would be most marked with metals of low melting points.

The observations of Prof. Fritzsche, who noticed that extreme cold produced upon tin an effect somewhat similar, but even more striking than that remarked by Mr. Williams in the case of iron, may be accepted as corroborating this idea.

The well known variations in the ductility of zinc, when under varying conditions of temperature, are also noticeable evidence of marked rapidity of such changes, where the range of temperature, within which the body remains solid, is narrow.

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* Experiments on Iron and Steel.

60. Reviewing the whole ground, it becomes evident that there still remains much interesting work to be done in determining the precise effects of variation of temperature upon the strength and ductility of the various metals, and, particularly, in ascertaining the modifications of the general law, which may be due to differences in physical and chemical structure, where they are combined with the metalloids, or united as alloys.

Some of those effects which have been attributed to changes of tenacity in the material may have been due, in some degree, to unequal expansion or contraction. It can hardly be doubted that such action often modifies, or even disguises, the change in character produced by real changes of intermolecular forces. It is certainly the fact that changes of molecular arrangement sometimes occur very slowly.

Ordnance of cast-iron has been found to gain strength slowly, but probably steadily, for years after its removal from the foundry; the familiar belief that razors, out of use, recover the cutting quality lost by constant employment, may be probably founded on fact, and the writer has often noticed that cold chisels and similar tools, when found after long disuse and exposure to the weather, seem to have regained the strength and endurance of edge, the loss of which had probably caused the workmen to throw them aside.

If this be the case, a sudden alteration of structure, such as may be produced by considerable changes of temperature, may cause a change of quality, which only a long period of time may counteract. Such action would evidently be most marked with brittle, and least noticeable with ductile, metals, and the fact is further illustrated by the circumstance that *iron* castings, not infrequently, are broken while cooling after removal from the mold, while *bronze* castings are very rarely thus injured.

61. It seems, finally, very probable that additional investigation will be found to confirm our deductions from experiments already made, and will justify the following

CONCLUSIONS:

1. That the number and the nature of those molecular forces which determine the physical condition of matter are not yet fully ascertained, but that these forces manifest themselves in, at least, three distinct modes of action, and, as thus exhibited, they are known as repulsion, cohesion and polarity.

2. That the force of repulsion is, apparently, heat-motion, or some closely related phase of energy; that the force of cohesion bears some resemblance to that of gravitation, but seems not to be identical with the latter, and that the force of molecular polarity, which determines the molecular relations of position, seems to bear some distant resemblance to that of magnetic polarity.

3. That the law which governs the variations in intensity of these forces with changes of intermolecular distances, is undetermined, and that it has not been expressed by any mathematical formula, except approximately and for a limited range.

4. That the magnitudes of the intermolecular spaces, and, consequently, the volume of any mass, are variable with changes in the relative magnitudes of the forces of cohesion and repulsion.

5. That the resistance offered to change of form is determined by the relations, in intensity, of the forces of polarity, and of those forces which determine intermolecular distances.

6. That, at the "absolute zero" (—461·2° Fahr.), cohesion and, consequently, the strength of the material, have their maximum value, heat energy having disappeared.

7. That, at very high temperatures, heat energy exerts a separating force between particles, which entirely overcomes the other forces, and matter assuming the gaseous state requires the action of extraneous force to preserve its volume unchanged.

8. That, at intermediate points, matter in either the solid or the liquid state exhibits a definite degree of separation of molecules, which is determined by the intensity of the repulsion due to heat motion, a position of equilibrium being assumed which, with the same substance, is invariable for the same temperature. The application of some kind of force is required to disturb this equilibrium and to produce this change of volume. The amount of this force is determined, for any given extent of disturbance, by the maximum value of cohesion for the substance and the quantity of heat which has been required to raise it from the absolute zero of temperature. The sum of the applied force, and of the force consequent upon the presence of heat motion, must exceed cohesive force to produce dilatation, while this cohesive force, added to the externally applied force, must exceed the force of repulsion to produce diminution of volume.

9. That the distinction between the solid and liquid states of matter is due to the action, in the former, of the force of polarity, which

gives stability of form, while in the latter this force is extremely feeble, and disappears altogether before the boundary line between the liquid and gaseous states is reached.

That combined stability and elasticity of volume may be produced by the equilibrium of attractive and repulsive forces, but that stability and elasticity of form demand the coexistence of cohesion and polarity.

10. That the general effect of increase or decrease of temperature is, in solid bodies, to decrease or increase their power of resistance to rupture, or to change of form, and their capability of sustaining "dead" loads.

11. That the general effect of change of temperature is to produce change of ductility, and, consequently, change of resilience and power of resisting shocks and of carrying "live" loads. This change is opposite in direction and, usually, greater in degree, than the variation simultaneously occurring in tenacity.

12. That marked exceptions to this general law have been noted, but that it seems invariably the fact that wherever an exception is observed in the effect upon tenacity, an exception also may be detected in the effect upon resilience. Those causes which produce increase of strength appear always to cause a simultaneous decrease of ductility, and *vice versa*.

13. That experiments upon copper, so far as they have been carried, indicate that, with that metal, the general law holds good.

14. That iron exhibits marked deviations from the law, between ordinary temperatures and a point somewhere between 500° and 600° Fahr., the strength increasing between these limits to the extent of about 15 per cent., with good iron. That this variation becomes more marked and the observed effects are more irregular as the metal is more impure.

15. That, above 600°, and, at temperatures below 70° Fahr., the general law holds good with iron, its tenacity increasing with diminishing temperature below the latter point, at the rate of from about 0·02 per cent to 0·03 per cent., for each degree Fahrenheit, while its resilience decreases in a much higher but not well determined ratio for good iron, and to the extent of reduction to one-third its ordinary value or less, at 10° Fahr., when "cold short," and, in the latter case, the set before fracture may be less than one-fourth that noted at a temperature of 84° Fahr.

16. That the viscosity, ductility and resilience of metals are deter-

mined by identical conditions, and that the fracture of iron at low temperatures has, accordingly, been found to be characteristic of a brittle material, while, at higher temperatures, it exhibits the appearance peculiar to ductile and somewhat viscous substances. The metal breaks, in the first case, with slight permanent set and a short, granular fracture, and in the latter with, frequently, a considerable set and the form of fracture indicating great ductility. The variation in the behavior of iron, as it approaches the welding heat, illustrates the latter condition in the most complete manner.

17. That the precise action of the elements with which iron is liable to be contaminated, and the extent to which they modify its behavior under varying temperatures, remain to be fully investigated, but that the presence of phosphorus, and of other substances producing "cold shortness," exaggerates to a great degree the effects of low temperature in causing loss of toughness and resilience.

18. That the modifications of the general law with other metals than iron and copper, and in the case of alloys, have not been studied, and are entirely unknown.

19. That these conclusions are sustained by experiments of both physicists and engineers.

The practical result of the whole investigation is that iron and copper, and probably other metals, do not lose their power of sustaining "dead" loads at low temperatures, but that they do lose, to a very serious extent, their power of sustaining shocks or resisting sharp blows, and that the factor of safety in structures need not be increased in the former case, where exposure to severe cold is apprehended, but that machinery, rails and other constructions which are to resist shocks, should have large factors of safety, and should be most carefully protected, if possible, from extremes of temperature.

It will be noticed that nothing in the evidence here quoted indicates crystallization or any change of molecular grouping to be consequent upon simple change of temperature.*

Stevens' Institute of Technology, Hoboken, N. J., May, 1873.

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* It is intended to consider this subject in a succeeding paper.

ABSTRACT OF A PAPER ON THE DURABILITY AND PRESERVATION OF IRON SHIPS, AND ON RIVETED JOINTS.

By Sir William Fairbairn, Bart.; F.R.S.*

The disaster which happened to the "Megæra" is first discussed, as showing the need of constant inspection of iron structures. That vessel was built by the author of the paper in 1849, and, in his opinion, would have been perfectly sound at the present time if her interior had been freely open to inspection, and if such inspection had been regularly carried out. Some years ago an alarming report was circulated as to the corrosion of the Menai Bridge. The author on that occasion visited the bridge, and found that no corrosion had taken place, careful attention to proper means of prevention having been sufficient to preserve the structure. The proved value of periodical inspections in the case of steam-boilers is then alluded to, and the author urges the importance of similar inspections of iron ships by the Admiralty and by private shipowners.

As respects riveted joints, the author first discusses the relative merits of machine- and hand-riveting, and points out that in machine-riveting there is much greater security that the rivets properly fill the rivet-holes. The rate at which riveting can be done is given as 16 rivets per minute with a lever riveting-machine, 10 rivets per minute with a steam riveting-machine, and 0.66 rivet per minute when the riveting is done by hand.

Experiments on Riveted Joints.

The author alludes, first, to the series of experiments on riveted joints which were communicated by him to the Royal Society in 1850. Those experiments showed that, taking the strength of a solid plate at 100, the strength of an equal width of riveted joint would be 70 if the joint were double riveted, and 56 if the joint were single riveted: in other words, 30 per cent. of strength is lost in a double-riveted joint, and 44 per cent. in a single-riveted joint. Since that time it has appeared to some engineers that the process of punching was injurious to the plates, and in many cases recourse has been had to drilling to form the rivet-holes. On this point the author was of opinion that with good iron no sensible injury resulted from punching the rivet-holes; on the other hand, with rigid and bad plates, the plate would crack between the rivet-holes, and the plate would have to be discarded. He regarded it as a distinct advantage of the punching-process that it thus tested the quality of the iron. It had been found in certain cases that the rivets sheared across with a less force when in drilled than when in punched holes, and this had been attributed to the sharpness of the edges of the drilled holes. This point seemed to require investigation, and experiments to elucidate it had, therefore, been made, the results of which are narrated in the paper. The theory that the sharp edges of drilled holes induced a cutting action, which diminished the strength of the rivets, had suggested to Colonel Inglis, R. E., to try whether a greater resistance in the joint could be obtained by purposely rounding the edges of the rivet-holes. Some experiments had been made for Colonel Inglis by Mr. Kirkaldy, from which it appeared that the resistance of the rivet was increased 10 per cent. by this rounding of the edges of the rivet-holes. The author has also experimented on this point, and the results of his experiments are given in the paper.

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* Proceedings of the Royal Society, Vol. xxi, 259.

A series of tables of experiments are then given, each result being fully discussed. The following table is a summary of results obtained by the author :

Experiments on the Ultimate Resistance of Rivets to Shearing.

No. of experiments.	Diameter of rivet, in decimals of an inch.	Sectional area of rivet, in decimals of a square inch.	Shearing resistance of rivet, in tons.	Shearing resistance, in tons per square inch.	Elongation of joint, in decimals of an inch.	REMARKS.
1.....	·84	·554	10·819	19·528	·190	Single shear; punched holes; machine-riveted.
2.....	·82	·528	10·879	20·606	·272	Single shear; punched holes; hand riveted.
3.....	·84	·554	10·257	18·514	·168	Single shear; drilled holes; machine-riveted.
4.....	·82	·528	10·739	20·339	·190	Single shear; drilled holes; hand-riveted.
5.....	·84	.554	11·221	20·254	·270	Single shear; drilled; edges of plates rounded; machine-riveted.
6.....	·82	·528	11·192	21·197	·240	Single shear; punched and countersunk; hand-riveted.
7.....	·84	·554	10·850	19·584	·160	Single shear; drilled and countersunk; machine-riveted.
8.....	·82	·528	11·234	21·276	·288	Single shear; drilled; edges rounded; countersunk; hand-riveted.
9.....	·82	·528	23·375	44·270	·340	Double shear; punched; hand-riveted.
10.....	·82	·528	20·684	39·174	·232	Double shear; drilled; hand-riveted.
11.....	·82	·528	24·313	46·047	·482	Double shear; drilled; edges rounded; hand-riveted.
12.....	·82	·528	26·464	50·121	......	Double shear; drilled; edges rounded and countersunk; hand-riveted. (This rivet did not shear. The plate broke away.)

The general conclusions drawn by the author from his experiments are as follows:

(1) *Joints with drilled holes are weaker and elongate less before fracture than joints with punched holes.* The average of four experiments on joints with drilled holes, compared with the average of four experiments on joints with punched holes, shows that the rivets in the former are 1·36 ton per square inch, or 6½ per cent., weaker than the rivets in the latter. The elongation is also 26 per cent. less with drilled than with punched holes.

(2) *Hand-riveted joints are somewhat stronger than machine-riveted joints.* The mean of three experiments on hand-riveted joints, compared with the mean of three experiments on machine-riveted joints, shows an excess of shearing resistance in the rivets in the hand-riveted joints amounting to 1·495 ton per square inch, or 7¼ per cent. The hand-riveted joint also elongates 26 per cent. more than the machine-riveted joint.

(3) *There is a decided increase in the strength of the rivet when the edges of the rivet-holes are rounded, so as to diminish their cutting action.* The mean of three experiments on joints with rounded holes, compared with the mean of three experiments on joints with unrounded punched holes, and with the mean of three experiments on joints with unrounded drilled holes, gives the following results:

		Shearing resistance of rivet.
Rounded holes,		21·517 tons per sq. in.
Unrounded holes,	punched,	20·958 " "
	drilled,	19·228 " "

This shows that the joint with rounded holes is, as regards the resistance of the rivet, 12 per cent. stronger than the joint with drilled holes, but only 2¾ per cent. stronger than the joint with punched holes.

As regards the apparent superiority of hand-riveting as compared with machine-riveting, the author observes that this is due to the fact that in hand-riveted joints the rivet is slightly hardened by being hammered after it is cold. In small experimental joints hand-riveting has therefore a slight advantage in strength; but the defects of hand-riveting are not likely to be exhibited in experiments on a small scale.

The experiments seem conclusive as to the inferiority of joints with drilled holes; and the author reiterates his conviction that the force used in punching plates is a valuable practical test of their quality, and tends to prevent the use of inferior iron.

Franklin Institute.

Proceedings of the Stated Meeting, May 21, 1873.

The meeting was called to order at the usual hour, with the President, Mr. Coleman Sellers, in the Chair.

The minutes of the previous meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported that at the stated meeting of the Board, held May 14th, donations to the Library had been announced from the following:

Machinery of the Arabia and La Plata. From B. H. Bartol, Esq., Philadelphia.

Bulletin of the National Association of Wool Manufacturers, Boston, Mass. From the Association.

Journal of the Society of Arts of London, for March, 1873. From the Society.

Annales des Ponts et Chaussées, Paris, France. From the Administration.

Monthly Notices of the Royal Astronomical Society, for March, 1873. From the Society.

Mittheilungen der K. K. Geogräphischen Gesellschaft in Wien, 1871. From the Society.

Statistical Report of the National Association of Iron Manufacturers for 1872. From the Association.

Proceedings and Statistics of the American Pig Iron Manufacturers' Association for 1872. From the Secretary of the Association.

The Report of the Superintendent of the U. S. Coast Survey, showing the progress of the Survey during the year 1869. From Prof. Benj. Pierce, Superintendent U. S. Coast Survey.

The Hub and Coach Makers' Magazine. From John H. Warder, Esq.

Annales de Chimie et de Physique for January and February, 1873. From the Editors.

Comptes Rendus Hebdomidaires des Sceances de l'Academie des

Sciences, from December 30th to March 24th, 1873. From the Academy.

Bulletin de la Société d'Encouragement pour l'Industrie Nationale, January to April, 1873. From the Society.

Revue Generale de l'Architecture et des Travaux Publices, etc. From the Editor.

General Register der Bände, xi—xx, des Jahrbuches und der Jahrgänge, 1860—to 1870, der Verhandlungen der K. K. Geologischen Reichsaustalt. From the Direction.

Jahrbuch der K. K. Geologischen Reichsanstalt Jahrgang, 1872, from October to December. From the Direction.

Verhandlungen derselben, 1872. From the same.

Third Annual Report of the President and Directors of the Lake Shore and Michigan Southern Railroad. From Chas. Paine, Esq.

Annales des Pontes et Chaussées, for January, 1873. From the Administration.

Annales des Mines, etc. Vol. ii, 1872. From the Administration.

Proceedings of the Academy of Natural Sciences, for January and February, 1873. From the Academy.

Transactions of the American Society of Civil Engineers. Proceedings of the meeting held January 17th, 1873. From the Society.

The Actuary likewise deposited the minutes of the several standing committees.

The special committees on the Horse-Power of Steam Boilers and upon Conflagrations, reported progress, and were continued by direction of the President.

The President next announced a paper upon an improved form of furnace for the desulphurization of gold ores, by Dr. Ira M. Phelps. The paper will be found published in the Journal of the Franklin Institute for August, 1873. The speaker described the progress made in the utilization of the sulphurous ores of the West, and explained from photographs cast upon the screen, the construction of a new furnace, which he claimed would accomplish the object more efficiently.

The paper elicited some discussion, which was participated in by R. E. Rogers, the President and the speaker.

The next paper announced was by Col. A. S. Gear, of Boston, Mass., upon A New Stone Working Machine. The speaker, after a general description of his device, and its peculiar advantages, referred to the samples of dressed and ornamental specimens of various stones, which lay upon the table for inspection, as evidences of the capacity of the machine.

The paper in question will be found published in the Journal of the Institute for October, 1873.

Under the head of deferred business, the President announced the consideration of a resolution, presented by Mr. S. Lloyd Wiegand, at the last meeting of the Institute, as follows:

> "*Resolved*, That a special committee of five members be appointed by the Chair, and announced at the next meeting of the Institute, to inquire into the expediency of introducing a system of uniform standard screw-threads, for tubing, and if, in their judgment, it appears expedient, to report such a system to be recommended by the Institute to manufacturers, for general adoption."

Mr. Wiegand moved to refer the subject of his resolution to the Committee on Sciences and the Arts. Carried.

Under the head of new business the President stated the business of the meeting to be the consideration of the motion of Mr. Robert Briggs, of which notice was given by Mr. Briggs at the last meeting, namely, to abolish Section 2d of Article xi of the By-Laws, referring to the Committee on Science and the Arts.

Mr. Briggs, in defence of his motion to abolish, made an address to the Institute, the tenor of which was to show that the period of usefulness of a committee, so constituted as the one under consideration, had passed.

Mr. John C. Cresson, in reply, gave a review of the past history of the Committee, and its opportunities for usefulness at present.

Mr. Orr followed with similar tenor, and in conclusion moved to indefinitely postpone the motion to abolish.

Mr. Cresson requested a withdrawal of the motion to postpone, in order that a square action might be had upon the motion to abolish. By consent, Mr. Orr withdrew his motion, whereupon a vote was taken upon the original motion of Mr. Briggs, which was lost.

Upon motion the meeting adjourned.

William H. Wahl, *Secretary.*

Proceedings of the Stated Meeting, June 18, 1873.

The meeting was called to order at the usual hour. In the absence of the President, Mr. Chas. J. Close was called to the chair.

The minutes of the last meeting were read and approved.

The Actuary submitted the minute of the Board of Managers, and reported that at the stated meeting held June 11th, 1873, the following donations to the Library had been received:

Geological Survey of Ohio and Maps. From the State Geologist.

Proceedings of the Scientific Meetings of the Geological Society of London for 1872, with Index 1861—1870. From the Society.

Monthly Reports of the Manchester Steam Users' Association for January, February, March and April, 1873. Annual Report of the same for 1872. From the Society.

Proceedings of the Royal Geographical Society of London, England, for May, 1873. From the Society.

Proceedings of the Literary and Philosophical Society of Liverpool, England, for 1871, 1872. From the Society.

Journal of the Society of Arts of London, England, for April, 1873. From the Society.

Journal of the Statistical Society of London, England, for March, 1873. From the Society.

A Compendium of the Ninth Census of the United States, June, 1870. From F. A. Walker, Superintendent of Census.

Smithsonian Contributions to Knowledge for 1873. From the Smithsonian Institution.

Annales des Ponts et Chausées for February, 1873. From the Editor.

The Actuary likewise reported the minutes of the several standing committees.

The special committees on the Horse-Power of Steam Boilers, and on Conflagrations, reported progress and were continued.

The President then announced a paper on Some Improvements in Weaving Machinery, by John Shinn. The paper gave a detailed description of a loom for weaving pile fabrics on stationary wires—the invention of the speaker,—an abstract of which will appear in the "Journal."

This paper was followed by one upon the American District Telegraph System. The subject was introduced and fully described by the Hon. Daniel M. Fox, after which a practical demonstration of its usefulness was made. The subject and remarks of the speaker are published in full in the "Journal" of September, 1873.

The Secretary next read his monthly report upon Novelties in Science and the Mechanic Arts.

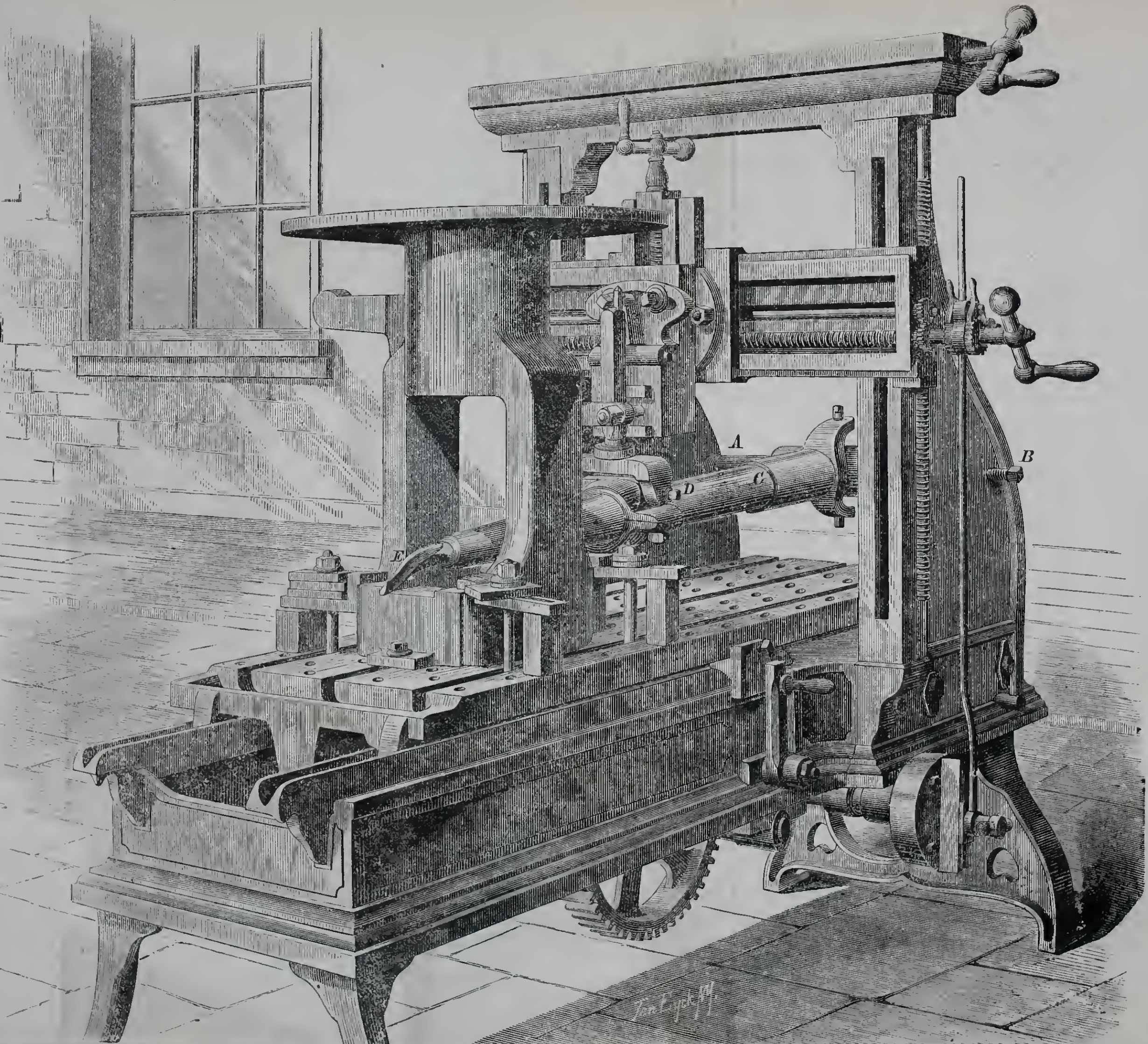
Under the head of new business, the Secretary announced the resignation of John H. Cooper as a member of the Board of Managers, and called attention to the clause in the by-laws of the Institute requiring such a vacancy to be filled. An election was thereupon ordered for a member of the Board, to fill the unexpired term of the gentleman resigned. The election resulted in the choice of John W. Nystrom.

After which the meeting adjourned.

WILLIAM H. WAHL, *Secretary.*

Fire-proof Construction.—At a recent meeting of the Franklin Institute, an improvement in the mode of constructing fire-proof floors and ceilings, combined with a system of ventilation, the invention of Mr. James Bounds, was exhibited. The invention consists of a truncated tile with the floor and ceiling surfaces in parallel planes, and overlapping the iron beams. The perforated sides of the tile, when in position, form a flue extending from wall to wall, connecting with flues in the latter—forming thus a series of ventilating flues, in which punctured register openings in centre of ceilings assist; and, in the event of fire, the system described is designed to afford an outlet for smoke and flame without injury to rooms above and below. The iron girders are isolated from the action of fire. The inventor claims that, from the simplicity of his construction, many expensive details in building may be dispensed with. It is further maintained that the tile by modification is capable of forming a level floor and ceiling arch without impairing either the fire-proof or ventilating properties of the construction, and that floors, roofs and partitions of any size, may be constructed upon the above plan.

The Suez Canal.—The returns of the Suez Canal Company for the month of August, according to the *Engineer*, make a very satisfactory show. It appears that 83 vessels passed through the canal during the 31 days of August, making an average of more than 2½ per diem, and yielding the company the sum of 1,660,000 francs transit receipts. The average cost per ship, it will be seen, by dividing the total receipts by 83, was just £800. It appears that the tonnage of the 25 vessels which passed through the canal during the third portion of the month made up an aggregate of 49,500 tons; if the other 58 vessels were of equal tonnage, the traffic must have been about 164,000 tons. The tonnage of the 25 vessels already referred to, gives an average of 1980 tons per ship, which shows that many of the vessels must have been of large size.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JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA.

FOR THE

PROMOTION OF THE MECHANIC ARTS.

Vol. LXVI.] NOVEMBER, 1873. No. 5

EDITORIAL.

ITEMS AND NOVELTIES.

Shaw's Planer Bar.—The invention herewith illustrated is designed to enable ordinary planing machines to perform the work of shaping and slotting machines, and to plane through, under, and over work through apertures, and between high projecting parts, in a thorough manner, never heretofore attempted on a planer, and excels the slotting and shaping machine, by reason of the extra length of work it will penetrate. A 5-ft. planer machine, provided with one of these bars at trifling cost, will plane through twenty inches, thus penetrating to a greater depth than a far more expensive shaping machine. A 12-ft. planer, provided with one of these bars, will plane through four feet of work. It will operate on a long or short stroke, and the ordinary feed of planer controls the feed of bar.

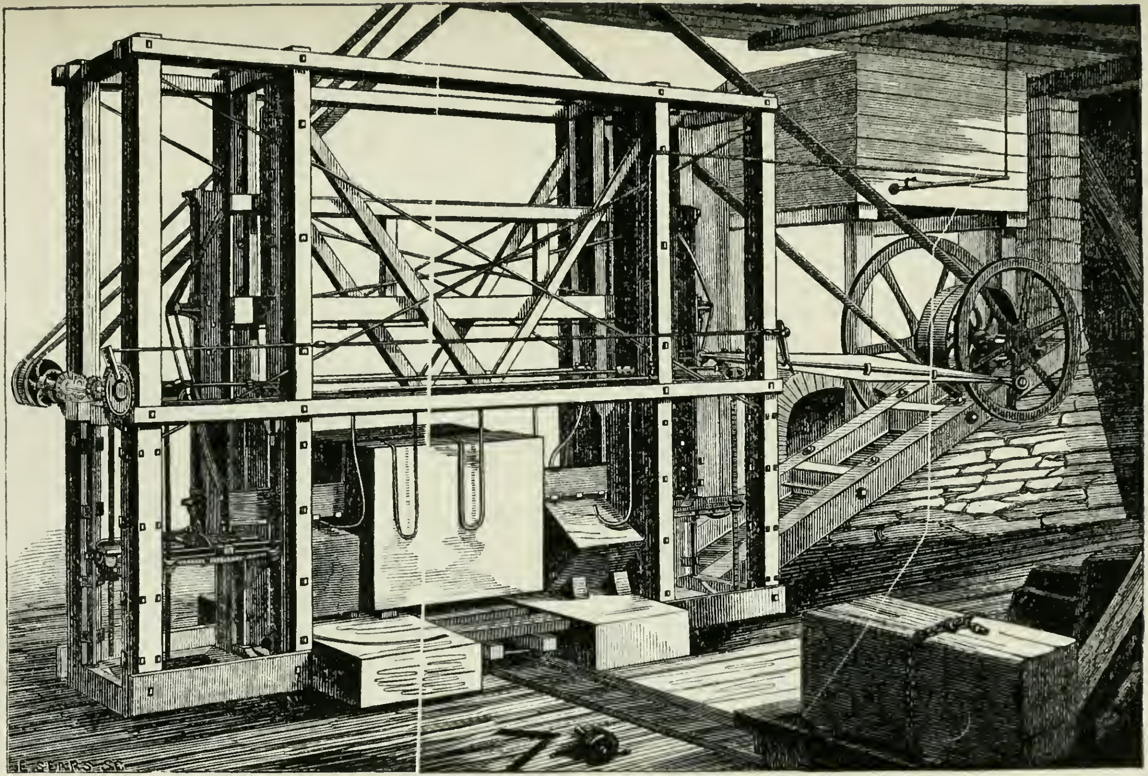
In brief, the planer bar will reach through work on planing machines, and thus serve to perform a large proportion of the labor of slotting and shaping apparatus, at, of course, a materially decreased expense. It consists of a heavy shaft A, which rides upon centres B. On this shaft the bar C is pivoted; so that by this mode of connection a universal joint is obtained, and the outer end of the bar rendered capable of motion in all directions. Near the centre of the bar is a pivoted box D, from which a pin projects, which is securely fastened to the tool-post and carriage. The bar is therefore subject to the movements of the latter, and is regulated by the ordinary feed motion of the planer. At E the tool end is represented as operating on the inside of a wide casting.

It is claimed that the ability of the device to reach through work is unlimited, and that it will plane one third the length of the planer; while its action being of an end-thrust character, it will cut all that the machine is able to pull without chattering. Our illustration presents so enlarged a view of the invention, that any farther details here are unnecessary to insure its comprehension.

Diamond Saw Machinery.—We are indebted to the *Manufacturer and Builder* for the following description:

A working model of Young's Diamond Saw is on exhibition, and in daily operation at the present Fair of the American Institute in its most improved condition. It illustrates clearly the distinct features of the invention, and cuts an astonishing amount of stone for the size of the machine.

The annexed engraving represents one of the diamond saws, such as have been and are now being erected by the Messrs. Young. It is a so-called reciprocating saw machine, the saw moving horizontally and attached to a frame like other stone saws; but in this machine diamonds are employed as cutting tools, in combination with the steel blade as a guide. The diamonds are set in "cutter blocks" at intervals upon the blade, and work horizontally as a true saw in the stone set beneath. Three distinct movements are applied in the cutting process; first, the ordinary to-and-fro motion, which impels the saw; second, a lift motion, by which the saw, after cutting the stone, is lifted in the cut from an eighth to a quarter of an inch, to enable it to return to its starting point without roughing out the diamonds; third, a graduated feed motion by which the saw is lowered after each stroke in cutting, in order to bring the tools again in contact with the stone. Each of these different motions is susceptible of being altered and arranged to adapt itself to the character of the stone—hard or soft—and to the feed desired. These motions are all automatic, and obtained by the simple application of mechanical principles. Indeed, it is difficult to decide which to admire most in this machine, the ease with which it works, the large amount of its productive power, or the simplicity of its construction. In regard to the expense of running such a machine, we ought not to omit the statement that the resist-



YOUNG'S RECIPROCATING DIAMOND SAW MACHINE.

ance of any stone under operation, is toward the diamond saw somewhat greater than it is toward an ordinary saw of iron used with sand. A given power cannot therefore run as many diamond saws as it can move ordinary saws. But in compensation, while an ordinary saw cuts on an average 15 inches of brown stone in a day, the diamond saw will do as much in half an hour.

It may be supposed that such saws may be liable to get out of order, but this is by no means the case; they work steady day after day, if only the diamonds are well set in their fastenings, and if at last one of them is, by any accident, loosened, it is at once caught by a wire sieve, and can be reset with little labor, and by any mechanic after a day's teaching.

Many of these machines are in practical daily use in this city, and in other localities.

A "Self-Breaking Hoisting and Lowering Machine."—A working model of this apparatus was shown and explained by the inventor, Walter Hart, of Philadelphia, at the last meeting of the Institute. Its construction is of a novel character. It performs work of the usual kind and also that not hitherto accomplished by any other single machine.

Its construction consists of parts so arranged that the weight of the object which is being moved by it, acts automatically as a stop to its own motion; the release from that stoppage, and such freedom of movement as may be desired, are effected by means of simple and easily managed devices. The breaking gear is a specially novel one. It acts directly with gradual though rapid effect on the rope or chain. The inventor claims and practically demonstrated that it moves two objects at one and the same time, each independently of the other; that it moves a lengthy object at any desired angle, changing that angle while hoisting or lowering it; that its workings are under thorough control, and the dangerous features arising from a descending weight are reduced to the breaking of the ropes or chains.

As a much called for means of safety in lowering boats from vessels with regulated speed and with an even keel, Mr. Hart explained and showed that a boat filled with its freight of persons, food, etc., could be raised and lowered through the aid of his machine by two men only, and that it was not possible to lower one end faster than the other. It can also be attached to suspended platforms with like effects, the evenness of movement both in boats and platforms being unaffected by the weight being heavier towards or at one end than the other. It can be fastened to the decks of vessels and to the heels of derricks, cranes and shears.

A Gas and Water Cut-Off.—This invention, known as the Seal and Brook's patent, was exhibited at the last meeting of the Franklin Institute, and is designed, according to the inventor's statement, to avoid the overflowing, freezing and bursting of water pipes, and to control the supply of burning gas.

The accompanying cuts represent the essential parts of the device, which consist of a lever and gauge (Fig. 1) to be placed in some conveniently accessible spot in any room of the house, and a spring valve (Fig. 2) in the cellar, the latter controlled by wires leading from the gauge. By regulating the valve opening, the flow of water and of gas through the meter may be controlled to a nicety, or the pressure may be removed entirely from the gas meter, pipes and fixtures during the day, if the certainty of avoiding all leakage is desired. In cases of accidents by fire or derangement of pipes, the complete control of the pipes afforded by this device is particularly valuable. The utility of the contrivance is too obvious to need further comments.

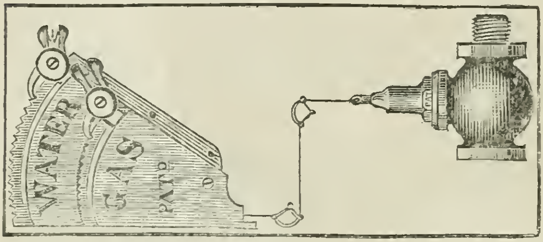


Fig. 1

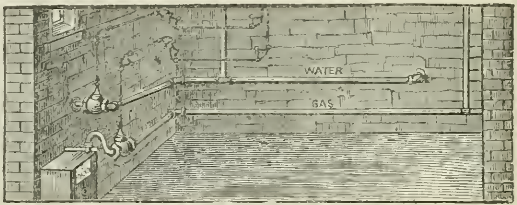


Fig. 2.

An Anti-Friction Journal—(James Eccles, Philadelphia).—The invention herewith illustrated is universally applicable to shafting, water wheel journals, elevators, steam and city passenger and freight cars, vehicles of every denomination, iron and steel rolling mills, steam engines of every kind, machinery of almost every kind, grind-stone journals, pivot and draw bridges, and other similar uses; and it is claimed that it will work under any pressure or speed, practically without wear, and without the use of a lubricant.

Journals and shaft bearings, made of various kinds of metal or other materials, as used at the present time, are too well known to require any description in this paper.

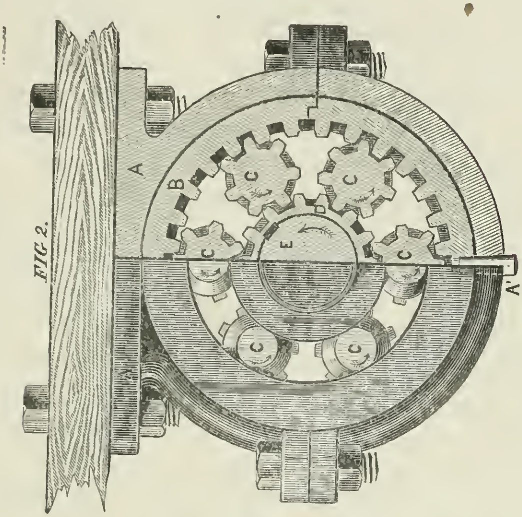


FIG 2.

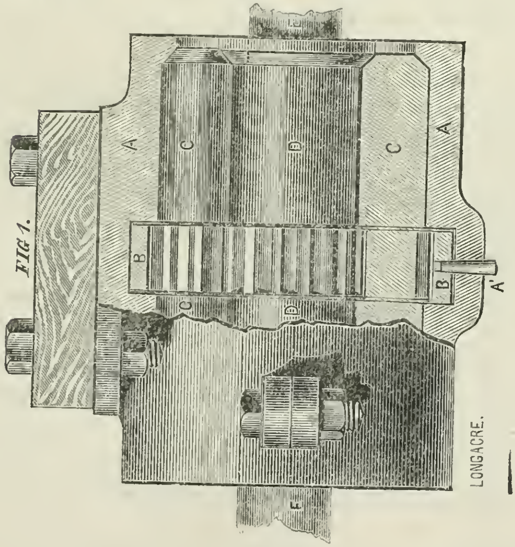


FIG 1.

Anti-friction rollers have been applied in various ways for at least a half century, but none (to the knowledge of the writer), have been successful. In many cases friction has been reduced to some extent by their use, but only for a limited period; for, after brief trial, they became useless through unequal wear, and consequently were abandoned.

The frictional journal box is made by forming gear teeth or cogs on the journal itself, or on an outer bush placed thereon, and gearing these teeth with corresponding teeth formed on a series of rollers, which gear into an annular geared wheel placed or cast within the journal box. The width of all the teeth should be about equal to one-third the length of the journal. The *pitch lines* of said teeth are parallel to, and coincide with, the respective *bearing* surfaces, so that the various surfaces may roll on to and around each other without any abrasion or friction. When the journal revolves, the bush rolls on the bearing surfaces of rollers, which then roll around the inner periphery of box. The whole may be made of cast steel or other metal, and will work with or without being lubricated. The two engravings herewith given show the device in front and side section.

This construction is claimed to be a practical frictional journal box, will work without being lubricated, and will last for an indefinite period of time.

The advantages to be derived from the use of a frictionless journal or shaft bearing, are too numerous and apparent to require any comment.

Guns and Armor.*—The biggest gun of which we have hitherto heard is the "Woolwich Infant," of 35 tons weight, which fires a 700-pound shot with a charge of 110 lbs. of powder; and the shot from this monster piece of ordnance could perforate the turret of the famous "Devastation" at any distance up to 500 yards. The armor plating of the "Devastation" is 14 inches in thickness, but an additional two inches in thickness would, it is said, render the vessel shot-proof against the biggest gun in the world. The English War Department has hitherto advanced cautiously from guns of 12 tons weight to 18, 25, and ultimately to 35 tons in weight; but they are now said to be contemplating the construction of one of 60 tons, the powder charge for which will weigh 200 lbs.; and it will throw a shot over half a ton in weight, which will be able to perforate a 20-inch turret.

Hardening Steel.—Amongst the American patents recently issued is one relating to the hardening of steel wire or thin steel. The process is as follows: The wire or thin steel is heated to a red heat by any of the known processes for uniform heating. It is then taken from this heat, and subjected immediately to a strong blast of air or gas, so as to cool it rapidly, varying the temperature of the air-blast and its degree of velocity, as may be required to give to the steel the requisite degree of hardness. After this the substance may may be tempered as desired for the purposes to which it is to be employed. The process may be made continuous, so that while one portion of the material is being heated another portion is under the blast of air, while another portion may be in the tempering.

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* Quart. Journ. of Science, iii, 539.

Coal Cutting Machinery in American Mines.—The following information concerning the Brown "Monitor Coal Cutter," in use at the "Coal Brook Mines" of Messrs. Niblock, Zimmerman & Alexander, at Brazil, Indiana, concerning which several descriptive articles have appeared in the technical press, may be of interest:

BRAZIL, IND., Oct. 9, 1873.

Editor of Journal of Franklin Institute:

DEAR SIR:—The Coal Cutter has been working pretty much all summer in our No. 3 mine, and has proved itself a practical success. Not merely experimental cuts have been made, but it has been in operation day after day, and has already mined hundreds of tons. Like all novelties, it will require increased experience on the part of the operators handling it, before its best results can be brought out.

Owing to the limited space prepared for its operations, it, as yet, has only been running about one-fourth of its time, as it must wait till the coal is taken away. More room, however, is being prepared, and in a short time it is hoped that its full capacity will be tested. It is expected that each machine, with seven men, will mine fifty tons each shift of ten hours, or about the output of twenty miners working with the pick.

I have been gathering some facts together with the intention of preparing a paper to be read before the Am. Inst. of Mining Engineers, at the Easton meeting, but fear I will hardly be able to do so now, as my time is much occupied. It will, however, afford me pleasure to keep you posted from time to time as to the workings of the cutter. I am yours, very truly,

JNO. S. ALEXANDER.

The Illinois and St. Louis Bridge.—The latest information concerning the work upon this structure, as derived from local sources, is the following:

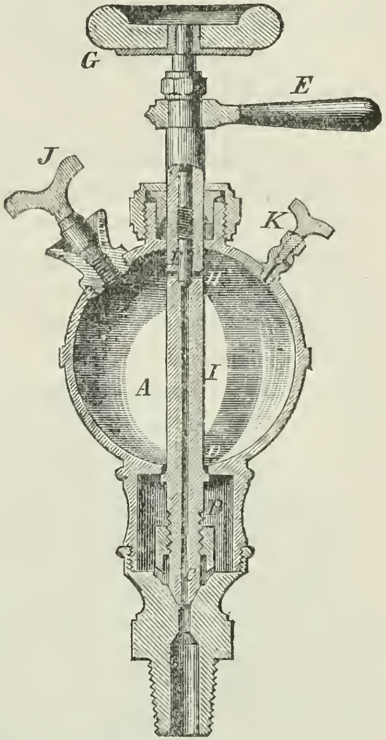
During the past week 79 tubes were put in position, making in all 612 which are in place. As the whole number to be contained in the structure is 1012, only 400 are now remaining. Yesterday the two outer ribs of the first span were completed, with the exception of placing the connecting tube in each of the four strands. They are ready to put in, and the couplings are fitted and lying on the bridge beneath. Early to-morrow (Oct. 20th) they will be put in place and keyed up, and the first span will be an accomplished fact. As soon as that is done there will be no further use for the heavy wooden scaffold now encumbering the span, and it will be removed as speedily as possible, thus affording a view of the finished structure. On the west side of the east pier six lengths of tubes have been placed, and the same number on the east side. On the east abutment the arch has been built out seven lengths, or a distance of eighty-four (84) feet. The prospects are that the spans will all be completed before the first of January next.

The tunnel which forms part of the western approach is making rapid progress. The excavations are nearly completed, and the arching proceeds at the rate of nearly 400 feet per week.

Fastening Rubber to Metal.—As rubber plates and rings are now used almost exclusively for making connections between steam and other pipes and apparatus, much annoyance is often experienced by the impossibility of effecting an air-tight connection. This is obviated entirely by employing a cement, which holds equally well to rubber and the metal or wood. Such cement is prepared by a solution of shellac in ammonia. This is best made by soaking pulverized gum shellac in ten times its weight of strong ammonia, when a shining mass is obtained, which, in three or four weeks, will become liquid, without the use of hot water. This softens the rubber, and becomes, after volatilization of the ammonia, hard and imperviable to gases and fluids.

A Combination Tallow Cup.—(Davis & Dubois, manufacturers, Philadelphia).—The object of the invention herewith illustrated is a steady or continuous lubrication of the cylinder and slide valves of a steam-engine, thus preventing all wear of the working parts and economizing power without the usual waste of lubricating material. It consists of a combination tallow cup, and is claimed to be equally well adapted to marine, stationary and locomotive engines, and also to afford results in every way satisfactory, during the period in which it has been in use.

In the sectional view annexed, A is the main reservoir, and B an auxiliary reservoir or charger; C is the main valve connecting directly with the cylinder, and D is a secondary valve, closing communication with the reservoirs, A and B. These valves are operated by handle E. F is the feeding valve, closed when main valve, C, is opened, and actuated by the wheel, G, serving to regulate the opening, H, in the stem, I. J is the inlet funnel, with valve-seated plug. K is an air-valve, to give vent while filling reservoir A.



The main valve, C, and stem valve, F, being closed by means of handle, E, and wheel, G, open valve K, and unscrew plug J; the reservoirs A and B are then filled with tallow, when valve K is closed and plug J replaced. By opening valve C, which closes valve D, the tallow in charger B is allowed to pass into the cylinder previous to starting the engine. When not used as a self-acting lubricator, the same operation of valves C and D is performed at intervals.

To render the action of the cup continuous, the valve F is opened (valves C or D being closed), when the steam, passing up through the stem I into the reservoir A, condenses and falls to the bottom, raising the tallow to a level with the openings H, from which it is sucked into the cylinder by every stroke of the piston as long as the supply of tallow remains. The reservoir is left filled with distilled water, which is let through the cylinder after stopping the engine by removing plug J and opening valves C and D. In case of any foreign substance entering the reservoir, it may be blown out while the engine is in motion, by allowing the steam to rush through the plug funnel.

Among the other advantages claimed may be noted strength and cleanliness, together with simplicity of construction; it is also stated that the device is steam-tight, precluding leakage, and thus dispenses with the usual means employed to absorb the waste. It may be used as an injector at stated intervals, or, by arranging the valves as above described, as a self-feeder. The cup is claimed to require filling but once a day to feed regularly, and to be economical in its expenditure of the lubricant.

The manufacturers state that it has elicited favorable testimonials from many leading engineers and master mechanics, and that its efficiency, in every respect, has been thoroughly demonstrated.

Irrigation and Drainage.—By D. S. Howard, *Mech. Engineer.*—There are two kinds of irrigation, natural and artificial. The obvious benefit of the former upon vegetation suggested, in the earliest ages, the necessity of supplying cultivated lands, in many countries where rains are not abundant, with water by mechanical means. The effect has been so universally beneficial that artificial irrigation has been adopted in all climates.

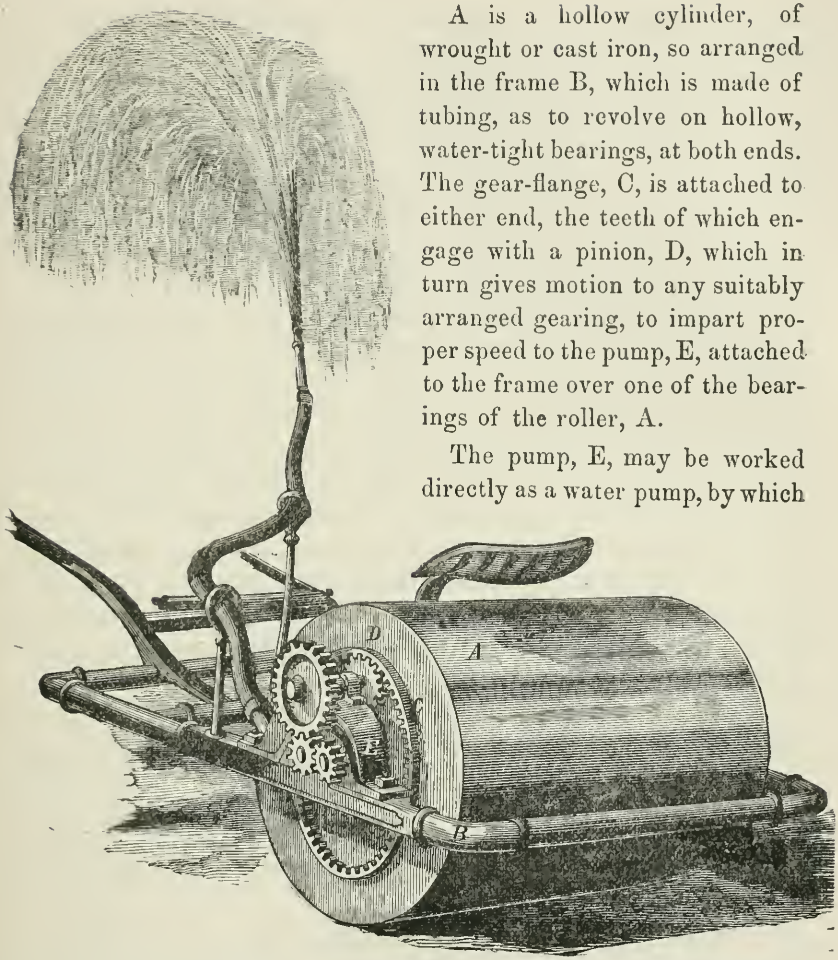
It has been ascertained that the more water disposed of by evaporation and proper drainage, the more productive the lands.

The absorbent and dissolving power of water for many gaseous and solid matters enables the falling rain to gather them from the atmosphere and soil, and to deliver them to the plants.

These considerations plainly require a system of irrigation that will furnish means to apply the water as nearly like rain as possible. This has been attempted, in a primitive manner, by the use of the hand watering-pot; the force-pump, worked by hand; and, in isolated cases, where a fall of water could be obtained to furnish the required power, a more effective manner of applying the water, through hose and sprinkler, has been resorted to, with proportionately good results.

The accompanying cut represents an irrigator and roller combined, a machine calculated to supply a long-needed improvement over the old laborious methods of hand-power irrigation, and capable of general application in localities not favored by nature with a plentiful and available supply of water, so situated as to furnish power to distribute itself.

A is a hollow cylinder, of wrought or cast iron, so arranged in the frame B, which is made of tubing, as to revolve on hollow, water-tight bearings, at both ends. The gear-flange, C, is attached to either end, the teeth of which engage with a pinion, D, which in turn gives motion to any suitably arranged gearing, to impart proper speed to the pump, E, attached to the frame over one of the bearings of the roller, A.



The pump, E, may be worked directly as a water pump, by which the water may be forced to any required height, and scattered to a considerable distance over any surface on either side of the track of the roller; or it may be so constructed as to be worked as an air-pump, to force air into the cylinder with a pressure sufficient to drive the water out with the necessary power to accomplish the same object. This will provide also for distributing liquid and powdered manures, and sprinkling plants and trees with poisonous solutions and powders, for the destruction of injurious insects, without injury to the working parts of the pump.

These machines may be built of any desired capacity, from the hand garden roller, for the horticulturist, to the largest and heaviest machines, operated by steam, for the rolling and sprinkling of streets.

When used as a roller alone, the weight may be perfectly adjusted by the amount of water retained, and the gearing disengaged by a lever, not shown in the engraving, actuated by the foot of the operator.

This feature of the machine will be appreciated when the practice of rolling crops with an adjustable weighted roller, adapted to the condition of the soil, shall become common.

The tubular form of construction not only increases the water capacity of the machine, but adds to its beauty and strength, as well furnishing a ready means of attaching hose at any most convenient point for effective use.

It is proposed to mount upon this frame a globular air-chamber, that shall have all its connections with the cylinder beneath water, when the machine is filled, which the hollow construction readily admits, the chamber to be used as a receptacle for storing compressed air, the machine while in motion charging itself with a power that can be used to eject a large portion of its contents when stationary, which will prove useful in applying poisonous fluids to the foliage of trees, and in extinguishing fires.

Spontaneous Combustion.—In a paper on the "Ignition of cotton by saturation with fatty oils," Mr. John Galletly communicates some information confirmatory of the generally received popular opinion regarding the spontaneous kindling of cotton and other open combustible substances which may happen to have imbibed animal or vegetable fatty oils.

The apparatus employed consisted simply of a box, in which the cotton saturated with the oily substances was placed, and the temperature then gradually raised in some cases to 130° F., the temperature which a body acquires by lying exposed to the vertical rays of the sun; and in others to 170° F., about the heat attained in the neighborhood of a steam-pipe, a heated flue, or in front of an open fire.

With boiled linseed oil the author found that shortly after the material had reached the temperature of his warm chamber (170°), the thermometer began to rise—from 5° to 10° every few minutes—so that in 75 minutes from the time the box was placed in the chamber, the heat indicated was 350° Fahr. At this point, smoke issuing from the box indicated that the cotton was in a state of active combustion; and on returning it to the free access of the air, it burst into flames. In another similar experiment, the temperature rose more slowly, but reached 280° Fahr. in 105 minutes, when, from the appearance of smoke, it was plain that the cotton was burning; and the whole mass was soon in a flame on being placed in a current of air. Raw linseed oil was found not to cause ignition of cotton so readily as the boiled oil, but under conditions similar to those of the above described experiments, active combustion was going on in one case in four, and in another in five hours. With rape oil under the conditions of the first experiment, the result was that the box and contents were found in ashes in ten hours—(the box being put up at night, the result was only observed in the morning.) Olive oil caused active combustion within five or six hours. With castor oil, the contents only charred on the second day of the experiment. Lard oil, (sp. grav. ·916), produced rapid combustion in four hours. Seal oil, (sp. grav. ·928), the same result in 100 minutes. Sperm oil gave negative results.

The author, as the result of his work, advances the opinion, from a comparison of raw linseed with lard and seal oils, that the statement is not altogether correct that "drying oils are more liable to spontaneous combustion than non-drying oils; and that the rate at which oxidation takes place does not depend chiefly on the presence of small quantities of putrifiable matters; but rather upon the particular oleine or liquid fat they contain.

The results of the experimental trials are stated to have been remarkably uniform. The author states that the ignition of cotton can be calculated on for any oil with about the same certainty as the point at which sulphur or other combustible matter inflames in air.

The heavy oils from coal and shale were found to effectually check the phenomenon above described; for when mixed with the oils above named, they gave no indications of heating whatever at 170° Fahr.

In view of the vagueness of definite information concerning this subject, which is a matter of importance to all who are engaged in manufactures employing these materials for any purpose, any systematic contribution to our knowledge of the conditions under which these oils and others may cause ignition, is of very direct interest.

The Utilization of Waste Products.—In an eloquent address delivered at the opening of Pardee Hall, Prof. R. W. Raymond discourses in the following terms upon the subject of our heading:

"Some one has well said that the utilization of refuse is the measure of civilization. That which the alchemists sought in vain their descendants are finding step by step, the 'Philosopher's Stone,' which will turn the most despised substances into gold. The illustrations of this are innumerable. I must be content with one or two. Few forms of refuse were more troublesome to dispose of, a few years ago, than the coal tar which accumulates in the manufacture of burning gas. At first it was used only as a rude kind of paint for iron, etc. Afterwards it was distilled, and yielded a volatile oil, with which Bethel impregnated wood to preserve it from decay. Then it was found that one of the distillates was a good material for removing spots and stains from cloth. But all these applications were found inadequate to dispose of the great quantity of tar that accumulated. Then came the grand discovery aniline, enriching the world with new and brilliant colors; and now even the refuse of the aniline manufacture yields anthracine and alizarine (artificial madder), the discovery of which is one of the most important events of the day, revolutionizing a great industry, and completely annihilating a branch of agriculture, to supply its place with a manufacture less expensive of labor, and hence in the end more beneficial to man."

The Pardee School of Mines.*—The new building, at Lafayette College, erected for the Scientific Department, now occupied by the classes, was dedicated by appropriate exercises, on Tuesday, October 21st. This magnificent structure cost over two hundred and fifty thousand dollars, and is the princely gift of Mr. Ario Pardee, the founder of the Scientific Department of the College. It consists of one centre building five stories in height, fifty-three feet front and eighty-six deep, and two lateral wings one on each side of the centre building, measuring sixty-one feet in length and thirty-one in width; four stories in height, including a mansard roof, the whole terminating in two cross wings forty-feet front and eighty-four feet deep, and four stories in height. The entire length of front, in a straight line, is two hundred and fifty-six feet. The material is the Trenton brown stone, with trimmings of light Ohio sandstone. It is heated throughout by steam and lighted by gas. The first floor is mainly devoted to the study of mining and metallurgy; the second contains the geological and mineralogical cabinets, a spacious auditorium, and smaller lecture rooms, reading rooms and professors' studies. The third floor is devoted to the engineers. The right wing is occupied by the mining engineers. A large drawing room occupies the lateral wing, while the cross wing embraces rooms for models and various professional purposes. The left wing is occupied by the civil engineers. The lateral wing comprises a drawing-room, and the cross wing is divided into rooms for lectures, working models, collections, and the like. On the fourth floor the same ample provision has been made for the chemists. The centre building is divided into two large rooms, one for technical collections and the other an assistant's room. The lateral wings are intended for quantitative and qualitative analysis. The cross wings at the extremity of the building are occupied by additional laboratories, lecture rooms and professors' studies. The fifth floor of the centre building is mainly occupied by laboratories for original researches. In determining what rooms were needed and the best arrangement of them, similar buildings in Europe as well as in this country were carefully studied, and liberal provision has been made in all the departments of instruction for every aid which has been devised for the most thorough and attractive teaching, and also for the prosecution of original researches.

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* U. S. Railroad and Mining Register.

The formal dedication of such a noble building, equalled but by few college edifices in the country, was an event of the greatest interest not only to the Alumni and friends of the College, but to all who are interested in educational matters, and of still more moment to capitalists who have invested or intend to invest their money in mines, furnaces, rolling mills, chemical works, machine shops, iron shipyards, or other fields of productive activity dependent for success on the best training of minds in technical science.

Editorial Correspondence.

To the Editor of Journal of the Franklin Institute:

Dear Sir,—In the September number of the "Journal" (p. 168) is illustrated an improvement in steam-engine governors. Looking over the list of American patents for 1872, I find this improvement the subject of one which was issued on the 19th of November of that year. There is no doubt that the patentee believed his invention to be new; and the reasoning which led to it original.

More than seven years earlier, however, another person followed the same course of reasoning to the same result, and embodied his ideas in an invention for which a patent was granted him March 14th, 1865, and which could scarcely be better described in one sentence than be the claim appended to the patent of November 19th, 1872; and a number of governors constructed by him have demonstrated the success of his invention.

That two persons separated by time or space, or both, should separately arrive at the same mechanical device, is not strange; and that the later of the two should, of his own knowledge, be aware of all previous similar inventions, could not possibly be expected.

The Patent Office, therefore, undertakes, for the sum of fifteen dollars, to inform him whether his feet have pressed virgin soil, or only trodden paths known before. And one would think that when the evidence lay within its own records of less than eight years past, fifteen dollars should amply pay for a sufficient examination, and reliable information; if not, the fee ought to be increased, or graduated according to the antiquity of the subject. A. B. C.

Philadelphia, *Oct.* 8, 1873.

Bibliographical Notices.

Elements of Physical Manipulation. By EDWARD C. PICKERING, Professor of Physics in the Massachusetts Institute of Technology. New York: Hurd & Houghton.

The object which this work seeks to accomplish is to place within the reach of students in the physical laboratories, which have now become an established adjunct to all of our large colleges and scientific schools, a text-book which shall serve them as a guide in the practice of the methods of physical investigation. In publishing this work, which is based upon the experience obtained in the Massachusetts Institute of Technology, Prof. Pickering has placed in the hands of teachers an excellent manual for instruction, and in the hands of the student a text-book the need of which has long been seriously felt. We shall, in our issues shortly following this, present to our readers specimen extracts from the work, which will be found of very general interest.

Civil and Mechanical Engineering.

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Entered according to the act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

Introduction.

In adding another to the many treatises relating to mechanics, and especially to that branch called mechanical engineering, it will be proper to explain that the purpose is to supply a want that none of the many text-books this far seem to have supplied—that of assisting the engineering apprentice in forming a true estimate of that which he has chosen as a profession, and pointing out the means of study that will lead to his understanding the principles, as well as the routine, of a shop course.

Aside from the fact that no books have been prepared with an especial view of assisting apprentices and adapted to the first stages of what we may call a mechanical education, there is the further fact that such books as are available treat of mechanical principles as consisting in mathematical formula and theoretical propositions only, overlooking the fact that such data are merely the symbols of mechanical principles, and not the principles themselves, and that a true understanding of mechanics is the result of a system of logical reasoning, which is only to be aided, and not supplanted, by rules, tables and formulæ.

A person may be a master of computations, or conversant with physics, and know little or nothing of practical mechanics, or may be a competent mechanic with but little knowledge of mathematical propositions, such as can be presented in books, and the great work of the apprentice is to connect and assimilate theoretical with applied mechanics.

It may be claimed that text-books can go no farther in treating of applied mechanics than general principles will reach—a very true proposition if the writer of mechanical books has no power of dealing with the subject farther than it is reached by theoretical deductions; but this furnishes no proof that the great share of a technical education, which consists in what may be called special knowledge, cannot be generalized and systematized the same as that part which is now explained on general principles.

Between physics, geometry and mathematics, and their practical application to industrial processes, or, to state it more plainly, between theoretical principles and the finished product of an engineering establishment, there is a wide space, filled in with intricate processes, with which text-books deal but sparingly, and sometimes not at all. This space has to be bridged over by the apprentice as best he can, and is that part which calls for his greatest efforts.

He may, for instance, study the geometry of tooth gearing; the construction of trains of wheels and the principles that govern their action; he may learn the principles of cycloidal and epicycloidal curves, but between all this and a finished wheel are the processes of pattern-making, founding and fitting, either of which require as much or more thought and study than the geometry of gearing, which subject furnishes page after page in our text-books, yet they are almost silent on the shop processes named.

The same rule applies in most classes of machinery; in machine tools, for instance, the apprentice has only to open a modern work on the subject, and he will find tables, formulæ and drawings to show the construction of machine tools, but seldom anything said upon the principles of their operation.

The apprentice, as soon as he enters the workshop, is at once brought in contact with machine tools of all kinds, and but little is gained in spending time in studying drawings and descriptions of them when the tools themselves are before his eyes; but connected with the operation of these tools are many intricate conditions that cannot be understood nor even conjectured by merely examining the machines, and much less from drawings of them. The conditions of operation, or principles of operation, are the points that the apprentice most needs to learn; what is meant by these principles of operation will appear in the course of this work.

Referring again to the books which are available to an apprentice, they are too often filled with tables, rules, formulæ and ready-made computations, which, like a list of gear wheel combinations stamped on a lathe, tend to relieve the learner's mind of that which is most important for him to study. The apprentice who refers to a table to select wheels for screw cutting will perhaps never learn to make the combinations mentally, and by using tables and rules to define mechanical questions, the principles may be entirely overlooked. Rules and tables have their place, and are merely a record of what has been determined and proved by crucial experiment or by mathematical demonstration, but the less the engineering apprentice deals in them the more he is likely to know of the principles upon which such rules are founded.

With books of an elementary character, until quite recently, the engineering apprentice has been no better supplied.

When it is considered how strong first impressions are and how they cling to the mind, it is easy to conceive how important it is to lay a proper foundation on which to rear a mechanical education, and when we examine school books that treat of natural philosophy and mechanics, and compare them with modern science and modern practice, it must be conceded that they furnish a bad foundation indeed for the learner to build upon.

As a first lesson in what is called mechanics, the student is taught to compute the power of levers, screws, wheels, wedges and other devices, which he is taught to call "mechanical powers," whatever that means; he is told that there are "three kinds of levers," and the terms used throughout are such as to confound power with mechanism, and prevent a comprehensive idea of force and motion, or the means of transmitting them. The student finishes such a study of mechanics with false conceptions of power and mechanism, which, as many will bear witness, clings to the mind for years, and may never cease to be a hindrance to acquiring a true appreciation of forces and the relations between power and mechanism.

A want of treatises that are especially adapted to the requirements of apprentices, is due in a great measure to the fact that practical engineers who have passed through a successful experience, and have gained that special knowledge which the apprentice most needs, as a rule have neither the inclination nor the incentive to write out the lessons that they could impart to others. The changes of mechanical manipulation are so frequent, and the apparent conflict that might arise between their opinions and established data would lead to adverse criticism, which such men do not care to invite; the result is, unfortunately, that the great mass of special knowledge gained by individual experience is lost, and mechanical text-books, of necessity, consist mainly in generalities that may be arrived at by theoretical deductions and inferences.

The purpose of these articles will be, in some degree at least, to supply this want of a medium between theory and practice, and to point out to the apprentice engineer that part of his education which may be termed special, and must be acquired mainly by his own efforts; to urge upon him the value of analytical reasoning, about even the most simple matters, instead of depending upon rules, tables and formula.

It will also be attempted to show the relations between principles and practice, not between figures and practice; for it must continually be kept in mind that figures are but the symbols of principles, the plan of tracing every process in the workshop to some general mode of operation as an antecedent, will be urged upon the learner, as the only means of cultivating that habit of reasoning, which alone can lead to a complete knowledge of practical mechanics.

The articles will contain no drawings, no figures or computations; these are already supplied in forms that leave nothing to be desired, and may be studied from other sources in connection with what is presented here.

The author, in preparing these articles for engineering apprentices, brings to his aid an experience of twenty-five years devoted to the construction of machinery and general engineering practice; and, as a considerable part of this experience has been devoted to the instruction of apprentices in applied mechanics and what is termed mechanical engineering, the plans of study which will be pointed out here are such as this experience has proved to be the most successful.

The articles have been prepared with a full knowledge of the fact, that what an apprentice may learn, as well as the time that is consumed in learning, are both to be measured by the personal interest that is felt in the subject studied, and that a strong personal interest on the part of an apprentice is essential to permanent success as an engineer. It is to be regretted that the difficulty of a statistical dryness and want of interest must always be a characteristic of any writing devoted to mechanical subjects. Some of the subjects treated here will be open to this charge no doubt, especially in the first part; but it is trusted that the good sense of the reader will prevent him from passing hurriedly over the first part to see what is said of casting, forging and fitting, at the end, and will cause him to read it as it comes, which will in the end be best for the reader, and certainly but fair to the writer.

PLANS OF STUDYING.

By examining applied mechanics and shop manipulation, the learner will see that the knowledge to be acquired can be divided into two departments—special and general: general knowledge, relating to tools, processes and operations, the nature and action of which may be understood from general principles, and without special or experimental instruction; the special knowledge, that which is based upon experiment, and can only be acquired by special, as distinguished from general sources.

To make this plainer it may, for example, be said that a knowledge of how to generate the teeth of wheels and their proportions, as a geometrical problem, is general knowledge that may be learned from books, and understood without the aid of an acquaintance with the technical conditions of either the mode of constructing or the manner of operating wheels; but how patterns should be made for casting wheels, or how wheels should be moulded or fitted, is special knowledge, and must have reference to particular cases.

The proportions of pulleys, bearings, screws, or other regular details of machinery, may also be learned from general rules and principles, but the hand skill that enters into their manufacture cannot be so learned.

The general design, or the disposition of metal in machine framing, can be to a great extent predicated upon rules and constants that have general application; but, as in the case of wheels, the plans of moulding such machine frames are not governed by constant rules or performed in a uniform manner; moulds may be made in various ways, and at a greater or less expense; the metal can be mixed to produce a hard or a soft casting, a strong or a weak one; the conditions under which the metal is poured may govern the soundness or shrinkage—things that are determined by special instead of general conditions.

The importance of a beginner learning to divide what he has to learn into these two departments of special and general has the double advantage of giving system to his plans and pointing out such part of his education as must be acquired in the workshop and by practical experience; the time and opportunities that might be devoted to learning the technical manipulations of a foundry would be improperly spent if devoted to metallurgic chemistry, because the latter may be studied apart from practical foundry manipulation, and without special opportunities for observation.

It may also be remarked that the special knowledge involved in applied mechanics is mainly to be gathered and retained by personal observation and memory, and that the first lessons, learned when the mind is interested and active, should as far as possible include whatever is special; in short, no opportunity of learning special manipulation should be lost. If a wheel pattern come under notice, examine the manner in which it is framed together, the amount of draught, and how it is moulded, as well as to determine whether the teeth have true cycloidal curves.

Once, nearly all mechanical knowledge was of the class termed special, and shop manipulations were governed by empirical rules and the arbitrary opinions of the skilled; the apprentice entered the shop to learn a number of mysterious operations, which could not be defined upon principles, and only understood by special practice and experiment. The arrangements and proportions of mechanism were also determined by the opinions of the skilled, and like the manipulation of the shop, were often hid from the apprentice, and what he carried in his memory at the end of an apprenticeship was all that he had gained. The tendency of this was to elevate those who were the fortunate possessors of a strong natural capacity, and to depress the position of those less fortunate in the matter of mechanical "genius," as it was called.

The ability to prepare proper designs, and to succeed in original plans, was attributed to a kind of intuitive faculty of the mind; in short, the mechanic arts were fifty years ago surrounded by a superstition, of a different nature, but in its influences the same as superstition in other branches of knowledge.

But now all is changed; natural phenomena has been explained as being but the operation of regular laws, so has mechanical manipulation been explained as consisting in the application of general principles, not yet fully understood, but far enough so that the apprentice may with a substantial education, good reasoning powers and determined effort, force his way where once it had to be begged.

The amount of special knowledge in mechanical manipulation, that which is irregular and modified by special conditions, is continually growing less as generalization and improvements go on.

The engineering apprentice, in estimating what he will have to learn, must not lose sight of the fact that what qualifies an engineer of to-day will fall far short of the standard that another generation will fix, and of that period in which his practice will fall. This I mention because it will have much to do with the conceptions that a learner will form of what he sees around him. To anticipate improvement and change is not only the highest power to which a mechanical engineer can hope to attain, but is the key to success. By examining the history of great achievements in mechanical science it will be seen that their success has been mainly dependent upon predicating future wants, as well as upon the ability to supply such wants, and that the commercial value of mechanical improvements is often measured by conditions that the improvements themselves anticipate; the invention of machine-made drills, for instance, was but a small matter, but the want that has grown up since their existence has rendered this improvement one of great value; moulded bearings for shafts was also a trifling improvement when first made, but it has since influenced machine construction in America in a way that has given great value to the invention.

It is generally useless and injudicious to either expect or to search after radical changes, or sweeping improvements in machine manufacture or machine application, but it is important in learning how to construct and apply machinery that the means of foreseeing what is to come should at the same time be re-studied. The attention of the learner can be directed to the division of labor, improvements in shop system, how and where commercial interests are influenced by machinery, what countries are likely to develop manufactures, the influence of steam hammers on forging, the more extended use of steel when cheapened by improved processes for producing it, the division of mechanical industry into special branches, what kinds of machinery may become staple, such as shafting, pulleys, or wheels, and so on; these are mentioned at random to indicate what is meant by looking to the future as well as at the present.

Following this subject of future improvement farther, it may be assumed that an engineer who understands the application and operation of some special machine, the principles that govern its movements, the endurance of the wearing surfaces, the direction and measure of the strains, and who also understands the general principles of the distribution of material arrangement and proportions, that such an engineer will be able to construct a machine, the plans of which will not be materially departed from so long as the nature of the operations to which the machine is applied remains the same.

A proof of this proposition is furnished in the case of standard machine tools, a class of machinery that has received the most thorough attention at the hands of our best mechanical engineers. Standard tools for turning, drilling, planing, boring and so on, have been changed but little during twenty years past, and bid fair to remain nearly the same in future.

A lathe or a planing machine made by a first-class establishment twenty years ago has, in many cases, the same capacity, and is worth nearly as much in value at the present time as the machines of modern construction—a test that more than any other determines their comparative efficiency and the value of improvements made.

The plans of the framing for machine tools has been altered, and many improvements in details have been added; yet, upon the whole, it is safe to assume that machine tools have reached a state of improvement that precludes any radical changes in future, so long as the operations in metal cutting remain the same.

This state of improvement, which has been reached in machine tool manufacture, is not only the result of the skill expended on such tools, but because they are the agents of their own production; machine tools produce machine tools, and a workman should certainly become skilled in the constructian of implements that he uses continually in his own business.

Noting the causes and conditions that has led to this perfection in tool manufacture, and how far they apply in the case of other classes of machinery, will indicate the probable improvements and changes that the future will produce. The functions and adaptation of machinery constitute, as already explained, the science of mechanical engineering. The functions of a machine is a foundation on which its plans are based; hence, machine functions and machine effects are matters to which the attention of an apprentice should be first directed. In the class of mechanical knowledge that has been defined as general, construction comes in the third place; first machine functions, next plans or adaptation of machines, and third the construction of machines. This should be the order of study pursued in learning mechanical manipulation. Instead of studying how drilling machines, planing machines or lathes are arranged, and next plans of constructing them, and then the principles of their operation, which is the usual course, the learner should reverse the order, studying first drilling, planing and turning as operations, next the adoption of tools for the purposes, and third plans of constructing such tools.

Applied to steam engines the same rule holds good. Steam, as a motive agent, should first be studied, then the operation of steam machinery, and finally the construction of steam engines. This is a rule that may not apply in all cases, but will serve to assist the learner in forming plans in most cases, and adopting a regular mode of proceeding in his studies.

To follow the same chain of reasoning further, and to show what may be gained by method and system learning in mechanics, it may next be assumed that machine functions consist in the application of power, and that power should therefore be first studied; of this there can be but one opinion. The learner who sets out to learn even the elementary principles of mechanics without first having formed a true conception or an appreciation of power as an element, is in a measure, wasting his time and squandering his efforts. Any truth in mechanics, even the action of the "mechanical powers" before alluded to, is received with an air of mystery, unless the nature of power is first understood; practical demonstration a hundred times repeated does not create a conviction of truth in mechanical propositions, unless the principles of operation are understood. An apprentice may learn that power is not increased or diminished by being transmitted through a train of wheels that change both speed and force, and he may believe the proposition without having a "conviction" of its truth. He must first learn to regard power as a constant and indestructible element, something which can be weighed, measured and transmitted, but not created or destroyed by mechanism—then the nature of the mechanism may be understood, but not before.

To obtain a true understanding of the nature of power is by no means the difficulty, for a beginner, that is generally supposed, and when once reached, the truth will break upon the mind like a sudden discovery and ever afterwards be associated with mechanism and motion whenever seen. The learner will afterwards find himself analyzing the flow of water, the traffic in the streets, the movement of ships and trains; or even the act of walking will become a manifestation of power, all clear and intelligible, without that air of mystery that is otherwise inseparable from the phenomena of motion.

If the learner will go on farther, and study the connection between heat and force, the mechanical equivalent of heat when developed into force and motion, and the re-conversion of power into heat, he will have commenced at the base of what must constitute a thorough knowledge of mechanics.

I am well aware of the popular opinion that such subjects are too abstruse to be understood by beginners—an assumption that is founded mainly in the fact that the subject of heat and motion are not generally studied and have been too recently demonstrated in a scientific way to command confidence and attention; but the subject is really no more difficult to understand in an elementary sense than that of the relation between movement and force illustrated in the "mechanical powers" of school books, which no apprentice ever did or ever will understand, except by first studying the principles of force and motion independent of mechanical agents.

It is to be regretted that there has not been books especially prepared to instruct mechanical students in the relations between heat, force, motion and mechanism. The subject is, of course, treated at great length in modern scientific works, but is not connected with the operations of machinery in a way to be understood by beginners.

A treatise on the subject, called "The Corelation and Conservation of Forces," published by D. Appleton, of New York, is perhaps as good a book on the subject as can at this time be referred to. The work contains papers contributed by Professors Grove, Helmotz, Faraday and others, and has the advantage of arrangement in short sections, that compass the subject without making it tedious.

In respect to books and reading, the apprentice should supply himself with references; a single book and the best one that can be obtained on each of the different branches of engineering is enough to begin with.

A pocket-book for reference, such as Molesworth's or Nystroms', is of use and should always be at hand.

For general reading, nothing compares with the scientific and technical journals, which are now so replete with all kinds of information that, beside noting the present progress of engineering industry in all parts of the world, they contain nearly all besides that the learner will require.

It will be found that information of improvements and mechanical progress that the learner may gather from serial publications can always be exchanged for special knowledge in his intercourse with skilled men, and what the apprentice may read in an hour can often be "exchanged" for experimental knowledge that has cost years to acquire.

Finally, I will say to the learner set out "*de novo*" in your plans, with a determination to succeed, and if your judgment commends it, with originality, only have system and method from the first, avoiding however, any course that will provoke rivalry or resentment on the part of others around you.

MECHANICAL ENGINEERING.

These articles, as already explained, are to be devoted to mechanical engineering, and in view of the difference of opinion that exists as to what mechanical engineering comprehends, and the different sense in which the term is applied, it will be proper to explain what is meant by it here.

I am not aware that any one has defined what constitutes civil engineering, or mechanical engineering, as distinguished one from the other, nor is it assumed to fix any standard here farther than to serve the purpose of defining the sense in which the term will be used; yet there seems to be a clear line of distinction which, if it does not agree with popular use of the terms, at least seems to be furnished by the nature of the business itself. It will therefore be assumed that mechanical engineering relates to works that *involve machine motion*, and comprehends the conditions of machine action, such as centrifugal strain, intermittent and irregular strains in machinery, the endurance of wearing surfaces, the constructive processes of machine making and machine effect in the conversion of material—in short, agents for transmitting and applying power.

Civil engineering will be assumed to works that do not *involve machine motion*, nor the use of power, and deals with the strength, nature and disposition of material under constant strains, or under measured strains, the durability and resistance of material, the construction of bridges, factories, roads, docks, canals, dams, and so on; also, leveling and surveying.

This corresponds to the most common use of the term civil engineering in America, but differs greatly from its application in Europe, where civil engineering is understood as including machine construction, and where the term engineering is applied to ordinary manufacturing processes for the production of staple articles.

Civil engineering, in the meaning assumed for the term, has become almost a pure mathematical science, constants are proved and established for nearly every computation, the strength and durability of materials, from long and repeated tests, has come to be well understood, and, as in the case of machine tools, the uniformity of practice among civil engineers and the perfection of their works, attest how far civil engineering has become a true science, and argues that the principles involved are well understood.

To prove how much is yet to be learned in mechanical engineering, we have only to apply the same test, and when we contrast the great variance between the designs for machines and the diversity of their operation, even when applied to similar purposes, their imperfection is at once apparent. Even if the rules of construction were uniform and the principles of machine operation as well understood as the strength and arrangement of material in permanent structures, still there would remain the great difficulty of adaptation to new processes that are continually being developed—if the steam engine, for instance, had forty years ago been brought to such a state of improvement as to be constructed with standard proportions and arrangement for stationary purposes, all the rules, constants and data of whatever kind that had been collected and proved, would have been but of little use in adapting the steam engine to railways and navigation in the present day. I revert to this change in machine adaptation that is constantly going on to warn the apprentice of the task he will find before him. Mechanical engineering has by the force of circumstances been divided up into classes, such as engineering tools, railway machinery, marine engineering, and so on, either branch of which constitutes a profession within itself, and the most thorough study will be needed to master general principles, and then a further effort to acquire proficiency in some special branch, without which there is but little chance of success at the present day. But few men, even under the most favorable conditions, have been able to qualify themselves as competent mechanical engineers sooner than at forty years of age.

To master the various details of machine manufacture, including draughting, founding, forging and fitting, is of itself a work equal to most professional pursuits, to say nothing of manual skill, and when we come to add machine functions and their application, generating and transmitting power, with other things that will necessarily be included in practice, the task assumes proportions that makes it appear a hopeless one; besides, the work of keeping progress with the mechanic arts calls for a continual accretion of knowledge, and it is no small labor to keep informed of the continual changes and improvements that are going on in all parts of the world, which may at any time modify and change both machines and processes.

One of the earliest cares of an apprentice should be to divest his mind of what I will call the romance of mechanical engineering that is almost inseparable from the views acquired in technological schools. He must remember that it is not a science he is studying, and that mathematics deal only with one branch of what is to be learned: special knowledge, or what does not come within the scope of general principles, must be gained in a most practical way at the expense of hard work, bruised fingers, and a disregard of much of what the world calls gentility.

Looking ahead into the future, he can see a field for the mechanical engineer widening on every side; as the construction of permanent works becomes more settled and uniform, the application of power becomes more diversified, and develops questions of greater intricacy. No sooner has some great improvement, like railway and steam navigation, settled into a system of regularity than new enterprises begin.

To offset the undertaking of so great a work as the study of mechanical engineering, there is the very important advantage of the exclusiveness of the calling—a condition that arises out of its difficulties. If there is a great deal to learn, there is also much to be gained in learning it. It is seldom, indeed, that an efficient mechanical engineer fails to command a place of trust and honor, or to accumulate a competence by means of his calling.

If a civil engineer is needed to survey railways, construct docks or bridges, buildings or permanent plant of any kind, there are scores of men ready for the place, and qualified to discharge the duties; but if an engineer is wanted to design and construct machinery, he is not so easy to be found, and if found there remains that important question of competency; for the work is not like that of constructing permanent works, where several men may and will perform the undertaking very much in the same manner and perhaps equally well. With machinery its success will be directly as the capacity of the engineer, who has but few precedents and still fewer principles to guide him, and generally has to set out by relying mainly upon his special knowledge of the operation and application of the machines that he is to construct.

ENGINEERING AS A CALLING.

It may in the abstract be claimed that the dignity of any pursuit is or should be as the amount of good it confers, and the influence it exerts for the improvement of mankind.

The social rank of those engaged in the various avocations of life has, in different countries and in different ages, been defined by various standards. Physical strength and courage, hereditary privilege, and other things that once recommended men for preferment, have now lost their importance or passed away entirely, and nearly the whole civilized world have agreed upon one common standard, that knowledge and its proper use shall be the highest and most honorable attainment to which people may aspire.

It may be useless or even wrong to institute invidious comparisons batween different callings which are all useful and necessary, and the matter is not introduced here with any view of exalting the engineering profession; it is even regretted that the subject is to be alluded to at all, but there is too much to be gained by the apprentice having a pride and love for his calling to pass over the matter of its dignity without calling attention to it.

Besides, the gauntlet has been thrown down and comparison provoked by the unfair and unreasonable place that the politician, the metaphysician and the moral philosopher have in the past assigned to the constructive arts. Poetry, metaphysics, mythology, war and superstition have, in their time, engrossed the literature of the world, and formed the subject of what alone was considered education. In a half century past all has changed; the application of the sciences in manufacturing, the transportation of material, the preparation and diffusion of printed matter, the utilization of natural forces, and other great matters of human interest, has come to shape our laws, control commerce, establish new relations between people and countries, in short has revolutionized the world. So rapid has been this change that it has outran the powers of conception, and people wake up as from a dream to find themselves governed by a new master.

Railways have done more to develope civilization than all the influence exerted since the world began by what was, a century ago, called "learning."

Considering scientific progress as consisting primarily in the demonstration of truths, and, secondly, in their application to useful purposes, we can see the position of the engineer as an agent in this great work of reconstruction that is now going on around us; it is certainly a proud one, but not to be attained except at the expense of great effort and a denial of everything that may interfere with the acquirement of knowledge during apprenticeship and the study that must follow.

The mechanical engineer deals mainly with the natural forces and their application to the conversion of material, and transport; his calling involves arduous duties; he is brought in contact with what is rough and repulsive, as well as what is scientific and refined. He must include grease, dirt, manual labor, undesirable associations and danger in apprenticeship, or else be content to remain without thoroughly understanding his profession.

THE CONDITIONS OF APPRENTICESHIP.

Were it not that moral influences in learning mechanics, as in all other kinds of education, lie at the bottom of the whole matter, the subject of this article would not have been introduced; but it is the purpose, so far as possible, to notice everything that concerns an apprentice and learner, and especially what he has to deal with at the outset.

To acquire information or knowledge of any kind successfully and permanently, it must be a work of free volition as well as from a sense of duty or expediency, and whatever tends to create love and respect for a pursuit or calling, becomes the strongest means for its acquirement.

The interest taken by an apprentice in his business is for this reason greatly influenced by the opinions that he may hold concerning the nature of his engagement.

The subject seems in the abstract to be one of commercial equity, partaking of the nature of ordinary contracts, and no doubt can be so construed so far as an exchange of "considerations," but no farther. Its intricacy is establishad by the fact that all countries where skilled labor exists have attempted legislation to regulate apprenticeship and define the relations between the master and apprentice; but, aside from preventing the abuse of power that has been delegated to masters, and in some cases forcing a nominal fulfilment of engagements, such legislation, like that intended to control commerce and trade, or the opinions of men, has failed to attain the objects for which it was intended.

This failure of laws to regulate apprenticeship, which existing facts fully warrant us in assuming, is due in a large degree to the impossibility of applying general rules to special conditions; it may be attributed to the same causes that makes it useless to fix values or the conditions of exchange by legislation.

What is needed is that the master, the apprentice and the public should understand the true relations between them, the value of what is given and what is received on both sides. When this is understood the whole matter will regulate itself without any interference on the part of the law.

The subject is an intricate one, and is, moreover, so changed by the influence of science and machinery, and a corresponding decrease in what may be called special knowledge, that rules and propositions that would fifty years ago apply to the conditions of apprenticeship, will at the present day be wrong and unjust; besides, the distinction between hand skill and mental skill, as I will term them, the exclusiveness or general character of the business, the irregularity of value, both of what is learned and the labor given in return, with other conditions not easy to determine even in a special case, makes the subject of apprenticeship a most difficult one to consider.

Viewed in the commercial sense, as an exchange of considerations or values, apprenticeship can be regarded like other engagements; but, as intimated before, the analogy ends here. What the apprentice gives as well ns what he receives are alike too conditional and indefinite to be estimated by ordinary standards.

The apprentice exchanges unskilled or inferior labor for technical knowledge, or for the privilege of the means for its acquirement.

The master is presumed to impart special knowledge, that has been collected at great expense and pains, as a premium for the assistance derived from the unskilled labor of the learner. This special knowledge may be imparted in a longer or shorter time; it may be thorough and valuable, or not thorough and almost useless.

The privileges of a shop may be such as to offset a large amount of labor on the part of the apprentice, or this privilege may be of such a character as to inculcate erroneous ideas, and teach inferior plans of performing work.

On the other hand, the amount that an apprentice may earn by his labor is governed by his natural capacity, and by the interest he may feel in advancing, also from the view he may take of the equity of his engagement, and whether he is able to place a proper estimate upon the privileges he may enjoy and the instruction received.

In many branches of business, where the nature of the operations carried on are measurably uniform, and have not for a long time been much affected by changes and improvements, the conditions of apprenticeship are more easy to define; but mechanical engineering is the reverse of this, it lacks uniformity both as to practice and what is produced, and is rapidly and continually changing.

As a rule, apprentices overrate their services, especially at the beginning, and set a value on what they perform far in excess of the true one.

To estimate the actual value of labor in an engineering works is not only a very difficult matter, but to some extent impracticable even by those of long experience and skilled in such computations; and it is not to be expected that a beginner will be able to understand the conditions that govern the value of his labor, and he is generally led to the conclusion that he is unfairly treated, that his services are not sufficiently paid for, and that he is not advanced rapidly enough.

With these conclusions in his mind no great progress will be made, and hence the introduction of the subject here. There is no hope of explaining the position of an engineering apprentice satisfactorily to those who have not passed through a course themselves, and acquired experience as a learner, workman, manager and master. It is impossible to form correct opinions of matters that we do not understand, and besides what may be pointed out here there will remain many points which the apprentice must accept upon the grounds of precedent and custom.

Technical knowledge and skill are considerations that may be bought or sold, but cannot be transferred from one person to another —has a commercial value, but cannot be gained as an education for commercial considerations, but must be paid for in a long term of labor, partially remunerated, both during apprenticeship and for a time in after-practice.

The commercial value of professional or technical knowledge is generally as the amount of time, effort and unpaid labor that has been devoted to its acquirement.

This value of technical knowledge is sometimes modified by the exclusiveness of some branch that has been made the object of special study. This exclusiveness is, however, becoming exceptional, as the secrets of manufacture and special knowledge are supplanted by the application of general principles, and should at this day not be estimated as a condition of importance; it is a kind of artificial protection thrown around certain branches of industry, that must soon disappear, as unjust to the public and unnecessary to success.

In business arrangements, technical knowledge and professional experience become capital, and offset money or other assets of a business; not under any general rule, nor even as a consideration which the law can define the value of, or prescribe conditions for, and for the same reasons that the law cannot prescribe conditions upon which such knowledge may be acquired.

This view of technical knowledge in relation to money in the organization of business firms, and wherever it becomes necessary to give it a commercial value, is the best and almost the only source from which the apprentice can form a true idea of the value of what he is to acquire during his apprenticeship.

When an apprentice enters the works to begin his trade, he at first forms an exaggerated estimate of what he has to learn; it presents to his mind not only a great undertaking, but a kind of mystery, which he fears that he may not be able to master. The next stage is when he has made some progress, and begins to underrate the task before him as it was at first overrated. In this reaction he imagines that the main trouble is past, that he has already mastered all the leading principles of mechanics, which is after all but a "small matter." In a third stage, the apprentice experiences a return of his first impressions as to the difficulty of his undertaking; he begins to see his calling as one that must involve endless detail, comprehending things which can only be studied in connection with personal experience; he sees "the horizon widen as it recedes," that he has hardly begun the task instead of having it completed, and almost despairs of its final accomplishment.

This last impression will last through life; practice will cause him to fix continually a higher estimate upon technical knowledge, until at the end of a long experience he will come to the conclusion that apprentices are the happy recipients of a bounty for which no adequate return is given.

Without assuming that this last estimate of mechanical knowledge is the true one, the apprentice is cautioned against underestimating such knowledge; it is the most intricate thing that he will have to deal with, not only during the course of apprenticeship but in various questions that are sure to arise in practice afterwards.

An engineer is expected to be, and should be, qualified to value and determine considerations in partnership and business, where this element of special knowledge and skill will often have to be estimated and balanced by money, time or other considerations.

In the workshop, mechanical knowledge of some kind is continually and often insensibly acquired by a learner, who cannot help observing the operations that are going on around him; he is continually availing himself of the experience of those more advanced, and learns by association the rules and customs of the shop, of the business, and of discipline and management. He gathers the technical terms of the fitting shop, the forge and foundry, notes the operations of planing, turning, drilling and boring, with the names and application of the machines directed to those operations. He sees the various plans of lifting and moving material, the arrangement and relation of the several departments to facilitate the course of the work in process.

He also learns where the product of the works is sold, discusses the merits and adaptation of what is constructed, which leads to considering the wants that create a demand for this product, and the extent and nature of the market in which it is sold.

All these things are technical knowledge, and the privilege of their acquirement an element of value. The common view taken of the matter, however, is that it costs nothing to a master to afford these privileges, the work must at any rate be carried on, and is not retarded by being watched and learned by apprentices. This is wrong; the very existence of a business may depend upon the profits from labor received in exchange for the privileges of apprentices, the operations of an engineering establishment are not to be confounded with those of regular manufactories; the first involves continual risk, and depends constantly upon the exercise of engineering skill, the latter is merely the conversion of material by processes that are constantly the same, and in which the engineering element has been furnished by those who constructed the machinery and made plans for the processes.

Viewed from any point, the privileges of engineering establishments have to be considered as an element of value, to be bought at a price, just as a ton of iron or a certain amount of labor in a commercial sense, as the equivalent of labor, material or money.

The value of such privileges is, however, comparative, and varies as the nature of the business carried on, and the manner in which the work is done, a matter that will be again alluded to in another place.

To turn now to the other side, without at this time noticing farther what an engineering apprentice receives, we will consider what is given in return—what accrues to the master from apprentice engagements.

Leaving out the question of premiums, we find on this side a single consideration, a certain amount of unskilled service performed by the apprentice.

This service is presumed to be given at a reduced rate, or sometimes without compensation, in return for the privileges of the works and the instruction that is received; but the value of this service is so hedged about with intricacies that it is almost as hard to determine the value of, as the considerations that it is rendered for.

The apprentice sees what his hands have performed, compares it with what a skilled man will do, and estimates it accordingly, assuming that his earnings are in proportion to what is performed; but this is a mistake, and a very different standard must be assumed to arrive at the true value of such labor.

Apprentice labor, as distinguished from skilled labor, has to be charged with the extra attention in management, the loss by a forced classification of the work, the influence in lowering the quality of the work and the amount performed by skilled men, the risk of detention by failure or the loss of material, and the imperfect character of the work performed. The apprentice must also be charged with the same, if not a greater expense than the skilled workman for light, room, oil, tools and office service.

Attempts have been made in the best-regulated engineering establishments to ascertain the value of apprentice labor, but, so far as I know, without satisfactory results in any case.

If not combined with skilled labor, it would be comparatively easy to determine the value of apprentice labor, but when it comes up as an item in the aggregate of labor charged to a machine or some special work constructed it is difficult to even approximate its worth.

Leaving premiums out of the question, and referring to such first-class establishments that do not demand them, or to cases in which premiums are not paid, there is no doubt of the common estimate placed by masters upon apprentice labor being in excess of, rather than below the true value.

A condition of apprenticeship, that is equally difficult to define with the commercial value of mechanical knowledge, or that of apprentice labor, is the extent and nature of the facilities that different establishments offer to the learner. In speaking of the mechanical knowledge, and the privileges of learners, and engineering works in a general way, it must, of course, be assumed that such works afford full facilities for learning some branch of work, by the best practice, and in the most thorough manner; but, in fact, such establishments are graded from the highest class on the best branches of work, where a premium would be equitable, down to the lowest class performing inferior branches of work, where there can be little if any advantage gained by serving an apprenticeship on any terms.

Besides this want, or difference of facilities that engineering establishments afford, there is the farther distinction to be made between an engineering establishment and one that is directed to the manufacture of staple articles.

This distinction between engineering and manufacturing is quite plain to engineers themselves, but in many cases is not so to those who are to enter as apprentices, nor to friends who advise them; and in every case where engagements are made there should be the fullest possible investigation as to character of the works where the engagement is intended; not only to protect the learner, but to protect regular engineering establishments in the advantages to be gained by apprentice labor. A machinist or a manufacturer who uses the muscular strength and the ordinary faculties only of men in his operations, can afford to and should pay an apprentice from the beginning a fair share of his earnings; but an engineering works that projects plans, generates designs and assumes risks based upon skill, and special knowledge is very differently situated in regard to apprentice labor.

The difference between engineering and manufacturing may be best explained by saying that to manufacture is to carry on processes for converting material; such processes being constantly the same, or approximately so, and such as do not call for the continual exercise of mechanical knowledge in the workmen.

The intricacies arising from the division of these branches of engineering, machine fitting and manufacturing, together with the indiscriminate application of the term "engineering" to even the coarsest branches of manufacturing in England, has led to very confused ideas upon the subject, and I offer the following propositions and suggestions that will be of use in selecting a place and in making terms for an apprentice course.

1st. The facilities afforded for engineering apprentices in any establishment is as the amount of skill and knowledge employed in its operations, the originality of the plans, the order and system with which the works are conducted and the character of the fitting perormed.

2d. The extent of an establishment is never a measure of its claims as a place of learning for apprentices, except it has been built up by superior engineering skill instead of commercial sagacity or a train of favorable circumstances. The larger the works the greater the division of labor; and assuming an establishment to represent a given amount of engineering skill, the smaller the establishment the better it is as a place of training.

3d. The public reputation of what is called engineering firms is as likely to be based upon commercial success as upon their professional ability, and is not always to be taken as a measure of the facilities they afford for apprentices, and as applications from those who do not understand the nature of engineering establishments are most likely to be made to popular firms, the inferences are that smaller firms will not only make better terms, but afford better facilities for the learner.

The name of having been an apprentice to a famous firm may sometimes have an influence in enabling an engineer to form advantageous commercial connections, but will in the end be of but little use ; such an apprenticeship is of value only as it has furnished substantial knowledge and skill, for every one will, sooner or later, come down to the solid basis of his actual abilities and acquirements. The engineering interest is by far too intelligent to recognize the shadow instead of the substance, and there is but little chance of deception in a calling that deals mainly with facts, figures and demonstrative skill.

The value of the facilities offered to the learner in different works, as I have attempted to show, vary in each case, and while there has been an effort to establish general rules and terms upon which apprentices should be engaged, such rules are of no use, and, if generally applied, would be unjust, either to the master or apprentice, in many cases. Each establishment should establish its own rules, and should also discriminate between different apprentices in the matter of their advancement. Whenever an engagement is to be made, it should be conditional as far as possible, leaving the position and progress of the learner contingent upon his exertions and the value of his services.

It is never safe to enter an establishment without first ascertaining its character from disinterested persons, who are qualified to judge of the facilities it affords. As a rule, every machine shop proprietor imagines his establshmant to combine all the elements of an engineering business, and the fewer the facilities for learners, usually the more extravagant this estimate ; so that opinions in the matter, to be relied upon, should come from extraneous sources.

In regard to premiums, it is a question to be determined entirely by the nature of the facilities that are allowed to the apprentice, assuming, of course, that the works can afford facilities, the value of which will exceed that of the services rendered by the apprentice. To include experience in all the departments of an engineering establishment, within a reasonable term, none but those of unusual ability can make their services of sufficient value to offset what they receive, and there is no doubt but that premium engagements, when the amount paid is based upon the actual conditions of the case, are fair and equitable. There is, however, this to be remembered, that the considerations that more especially balance the premium, such as a term at draughting, designing and office service, can be mainly acquired by self-effort; while the practical knowledge of moulding, forging and fitting cannot; and an apprentice, who has good natural capacity, may, by the aid of books and such opportunities as shop experience affords, qualify himself very well without including the premium departments in his course.

Finally, it must constantly be borne in mind that what will be learned is no less a question of facilities than effort, and that the means of study are closed to none who, at the beginning, form proper plans and follow them persistently.

(To be continued.)

BELTING FACTS AND FIGURES.

By J. H. Cooper.

(Continued from page 236.)

"Belting, gearing and unbalanced pulleys or wheels represent transverse strain, which must be a matter of judgment rather than estimates. It would be folly to predicate the transverse strain upon a shaft as being simply the tension of belts, or the strain of gear wheels working under ordinary conditions. A rule in the author's practice has been in the case of belts to provide sufficient strength in shafts and supports to tear them asunder, without damage to the machinery. This is the only safe rule, for there is no means of always guarding against winding belts.

"Calling the distance between the hangers or bearings b, the diameter of the shaft d, and width of belt w, a rule for ordinary cases would be $w = d^2$ and $d \times 25 = b$. This is, of course, arbitrary; and presuming the pulleys to be in the centre between the bearings, and not more than five faces in diameter. In proportioning shafts for belting, much must be left to judgment, and be dictated by that peculiar sense of realizing what is wanted from previous experience.

"There are, in fact, so many obscure conditions that have to do with the matter, that any rule must be an arbitrary one, if given for general application. The above is, however, safe, so far as strength is concerned, for gearing, shafts must, as a rule, be stronger than for belts. The motion is positive, and lacks the elasticity that exists in belt connections. Shafts are in general made strong enough to crush cast-iron gearing; practice has given larger proportions to shafts that receive gearing, no doubt for the reasons stated, that of positive motion; yet the proper plan in the construction of wood machines would in all cases be to drive the first movers with belting so proportioned and arranged that it would be sure to yield before breaking the gearing. Ordinary belting, with its surfaces dry, as they must be when operated on wood-working machines, has much less driving power than the belting on metal-working machines, when the surfaces become covered with oil or gum, and the leather soft and pliable. Assuming the belts to be dry, a good rule for belting and gearing for feeding wood machines would be as follows: Let V be the velocity of the belt, and v that of the pinion or first mover, the width of the belt to be the same as that of the gearing $\frac{V}{6} = v$; or, in other words, the diameters of the pulleys to be to the pinion as 6 to 1, with equal faces: variations as to relative width should be directly as the proportion between pinion and pulley; if, for instance, the face of the pinion was reduced to 2 inches, and the belt remain 3 inches wide, their velocities would require to be $v \times 4 = V$, or diameter as 1 to 4, the diameter of the shaft being equal to the square root of the face of the pulley. There would with these proportions be no danger of breaking either shafts or gearing, it being understood, of course, that in a train of gearing such as is used in planing machines, the force and pitch of each wheel and shaft should be inversely as their velocity.

"The belting for circular saws is, as a rule, too narrow, or upon pulleys of too small diameter. To drive a saw well and without injurious strain upon the bearings, belts should be one-third the diameter of the saw in width, and the pulley equal in diameter to the width of the belt, which is a very simple rule, and does not give any more than the needed driving force, under fair conditions.

"One-fourth the diameter of the saw for the diameter of pulleys on cross cutting spindles. Their faces can be one and a half diameter in length.

"That speed should be an element in estimating belt contact is apparent in looking at the spindle pulleys in wood-cutting machines. The degree in which belts are affected by centrifugal force in running at high speed is dependent upon the tension, weight and flexibility of the belt and the diameter of the pulley. At 5000 feet a minute, with belts of ordinary harness leather, running on pulleys six inches or less diameter, the amount of contact is not more than three-fifths of what would be shown in a diagram, and is often much less. Coupled with this, however, is the strange fact that the tractive force does not seem to be as constant as the amount of contact. That the pressure on so much of the surface as has contact is increased by the belt 'lifting,' is unquestionably the case, but it hardly accounts for the want of proportion between the power transmitted and the amount of contact. This matter is mentioned as an experimental fact, and merely to stand as a reason for saying that the width of the belts need not be predicated directly upon the pulley contact for high speed spindles.

"For spindles having unusually high speeds, the writer has found belts of cotton webbing to be preferable. Such belts, if closely woven and of the best material, will, when waxed, be found to have a high tractile power and wear well, while their comparatively light weight avoids their lifting from centrifugal force.

"The convexity of pulleys to keep belts central should be sufficient for the purpose, and no more. It is difficult to account for the practice of many builders of wood machines, especially in England, who give a degree of convexity to pulleys that interferes with the contact and tends to the destruction of the belt, unless both pulleys have their faces the same, a thing impossible in the case of shifting belts. Without entering into an examination of the laws and conditions that govern the matter, the following rule is given:

"For pulleys from two to twenty-four inches face, the convexity should be from one-eighth of an inch to one-sixteenth of an inch to a foot, graduated inversely as the width of the faces; for pulleys of narrower face, the convexity can be slightly increased.

"This is quite sufficient to govern the running of belts, and a necessity for more can safely be construed as a fault in the position of the shafting.—*J. Richard's Treatise on Wood Machinery. E. & F. N. Spon, London.*

"*Loose pulleys.*—I have had great trouble in procuring a small loose pulley that would stand running at a high rate of speed with a very tight belt. After trying a large number of different kinds, of wood and iron, with long and short bearings, bushings of Babbitt, copper, etc., none of which would stand more than two months, I at last procured some sole leather; I put the flat surfaces together and bolted through with four bolts; after boring and turning I soaked it well in oil and put in place. It has now been running about one year, and is, apparently, as good as new. It requires very little oil." —*G. P., in Scientific American*, September 20, 1873.

(To be continued.)

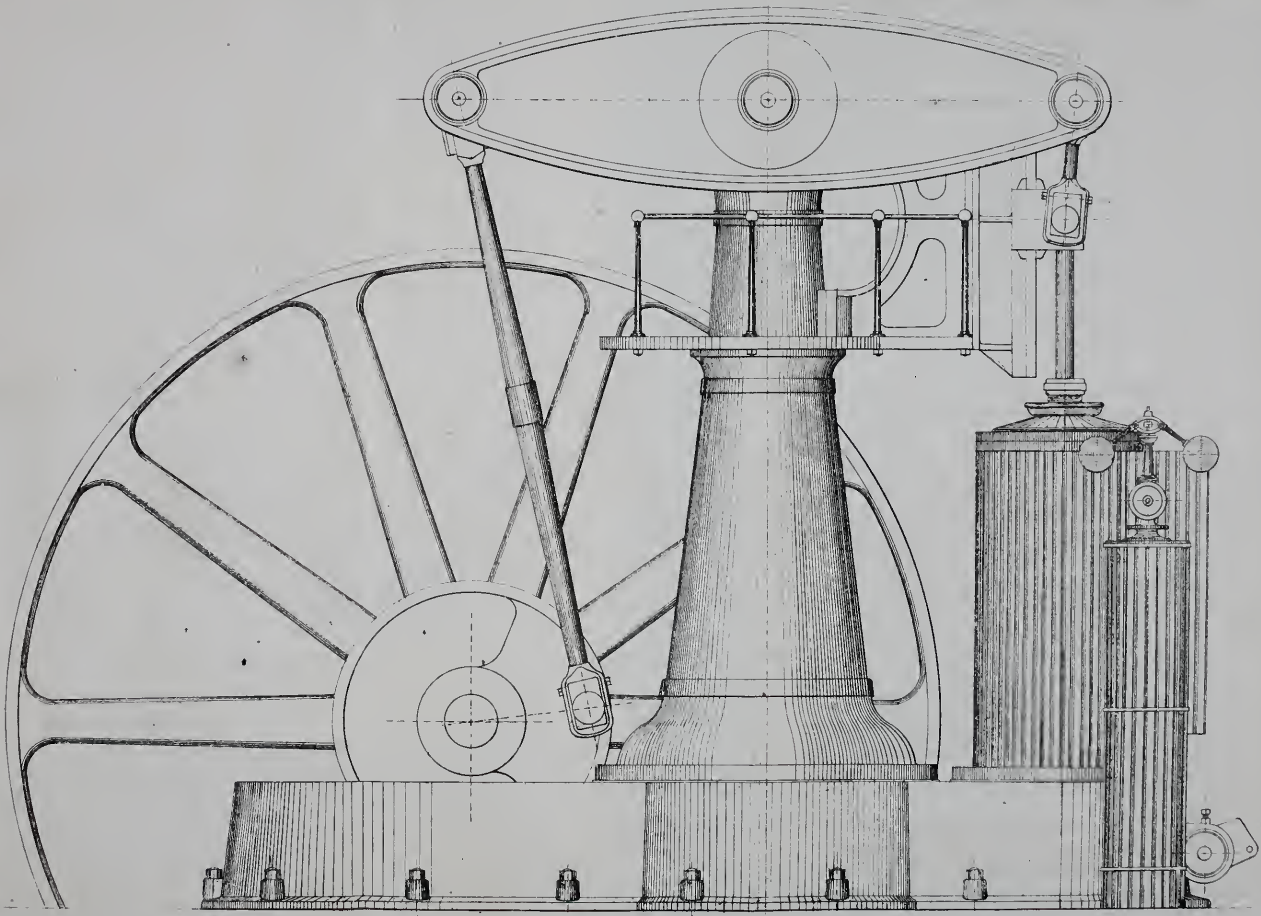
COMPOUND BEAM ENGINE AT THE WOOLEN MILLS OF MESSRS. JOHN AND JAMES DOBSON, PHILADELPHIA.

The motive power of the carpet department of the factory is furnished by a compound beam engine, the illustrations showing a side elevation of the high pressure engine and a plan of both. The high pressure cylinder is 26 inches, the low pressure cylinder 50 inches diameter; both have four feet stroke, and make fifty revolutions per minute. The cylinder, beam column and shaft-bearing of each, rest upon deep box bed plates, having rounded ends and centre and closed top. The rock shaft-bearings are cast to one end of each bed and the crank wheel pit formed in the other.

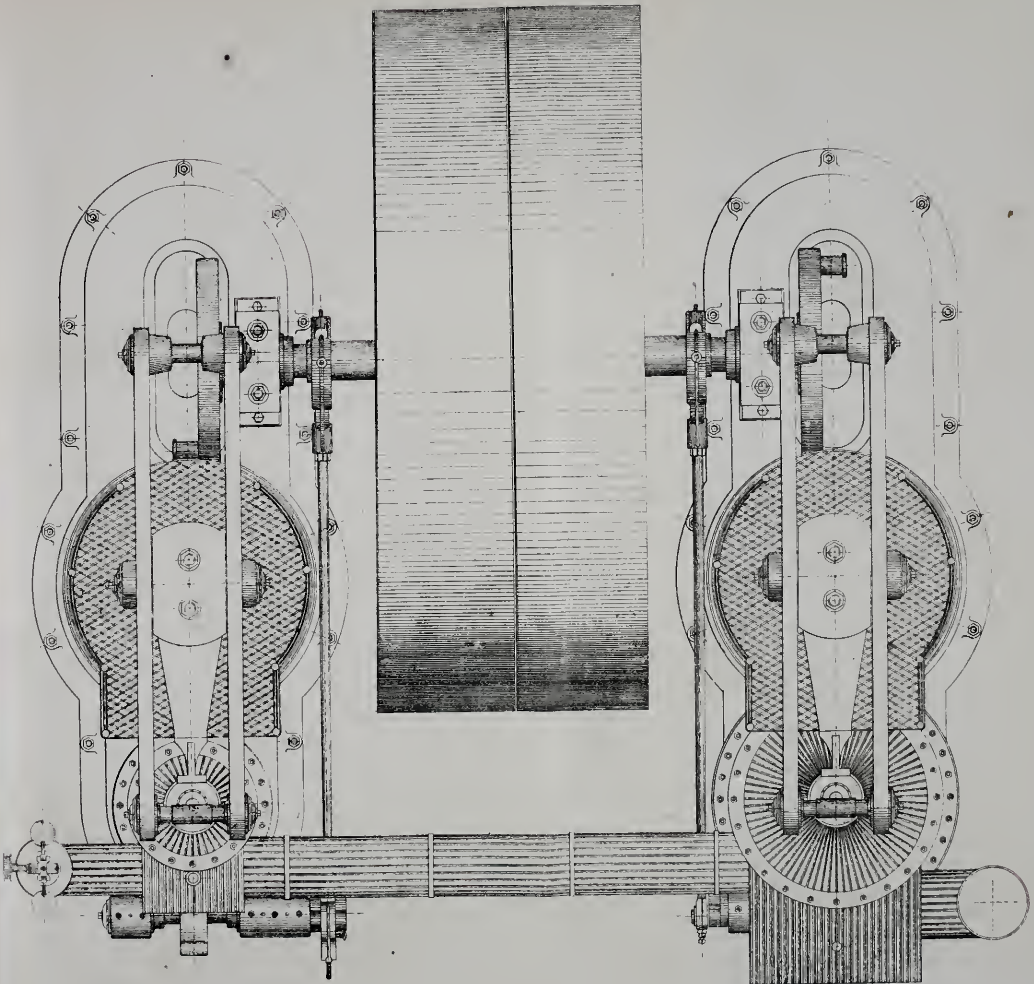
The engines are alike in every particular except the cylinders, and are connected to one shaft, upon which are secured two 16 feet diameter fly-wheel pulleys, 37 inch face, and each at present carrying a 30 inch wide double leather belt. These belts run over eight feet pulleys on the line shaft which is extended into the engine room from the factory.

The high pressure cylinder is provided with two plain D slide valves, the low pressure cylinder with one, and all are disburdened of steam pressure by packed rings—one on the back of each. The speed is regulated by an ordinary centrifugal ball governor, operating a balanced valve in the steam-pipe. The high pressure cylinder exhausts directly into the steam-chest of the low pressure cylinder, through a straight connecting pipe. The cranks and valves of both engines are so set that the low pressure piston begins to receive the exhaust steam from the high pressure cylinder at the moment of its release. The crank pins are carried by loaded wheels counterweighing the pistons. In each engine a slipper guide, embraced by the cross head, is bolted to the beam column, but has no connection whatever with the cylinders. This arrangement allows the cylinders to expand and contract without displacing the line of the guides, and possesses all the requisites of strength and stability, at the same time permitting a similar disposition of guide and cross head to each engine, which would be difficult to produce over cylinders of such different diameters.

Each engine has two beams, with all the bearings between them—the centre pin resting in two boxes, which are secured in a cylindrical block adapted to a corresponding cavity in the top of the beam column, and which may be turned about the axis of the column, and se-



COMPOUND BEAM ENGINE—Built at People's Works, Philad'a.



COMPOUND BEAM ENGINE—Built at People's Works, Philad'a.

cured in any position thereto by adjusting screws. Each box can be raised vertically as may be necessary by wear from time to time. Any desired plane of vibration for the beam can thus be obtained by simple means of adjustment. The cylinders are cased with walnut staves, held in place by polished nickel bands, and are placed at such height that all water of condensation in the steam-pipes is returned to the boilers.

A feed water heater of unusually large dimensions forms part of the exhaust pipe between the low pressure cylinder and the condenser, and serves the double purpose of heating the feed and partially condensing the steam—a plan which was deemed necessary in this case, as the water used for injection is mixed with the waste liquors from dye-houses, and is not fit to be used again for feed.

The heater, condenser, and air and feed pumps are placed below the engine room floor. Steam is supplied by twelve plain cylindrical boilers, 36 inches diameter by 36 feet long, in nests of three each.

These engines were designed and built at the "People's Works," corner of Front street and Girard avenue, Philadelphia.

THE CLEVELAND WATER-WORKS TUNNEL.*

The announcement of the fact that the water-works tunnel is completed throughout its entire length, will be received by all our citizens with unalloyed satisfaction. It will insure to the city, for an indefinite period in the future, an abundant supply of good water, free from the nauseous impurities caused by the drainage of oil refineries, slaughter-houses and sewers, which have at times rendered the water almost totally unfit for domestic use. The new dispensation which is just dawning upon us has long been eagerly looked for, and very many of our citizens had begun to lose faith in the success of the tunnel project. Month after month and year after year passed, and much of the time but slow progress was made, with an occasional accident that threatened disastrous results, and the unpleasant idea was gradually taking possession of the public mind that the enterprise would fail, that two or three hundred thousand dollars would be thrown away, and no relief afforded from the noxious liquid that we had been compelled to use under the name of water. But the engineer, John Whitelaw, Esq., the contractor, A. A. McDonell, Esq., and the Water Commissioners, have been steadfast in the belief that success would at last crown their efforts, and now they have their reward, after years of anxiety and labor. In this connection a brief history of the enterprise will be read with interest by many.

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* Cleveland Daily Herald, Oct. 13, 1873.

The necessity of a supply of pure water had long been felt. The complete success of the Chicago water-works tunnel induced the belief that a similar plan was the only means that would give to Cleveland the needed relief. Borings were carefully made to ascertain the character of the ground under the lake. For the depth of forty feet or more, at all points a hard blue clay was found, which was in the highest degree favorable for the work. Had it not been for subterranean springs and quicksands which were encountered at various points, and which at times seemed to make the result doubtful, the tunnel would doubtless have been completed a year and a half ago.

The shore shaft was sunk in the fall of 1869, the work being commenced in August of that year. After going down about eighty-five feet, the lateral excavation was begun, and continued some three hundred feet. Up to this point the work was done by the Water-Works Department, under the direction of the Commissioners. The object was to decide, by actual test, the feasibility of the project, and afford a basis for proposals to do the work by contract. When this had been, apparently, fully demonstrated, bids were invited, and the contract was subsequently awarded to A. A. McDonell, Esq., of Chicago. Many a man not possessing his indomitable perseverance, determination and "pluck" would have abandoned the enterprise long ago, in the face of all the unexpected dangers and disasters he encountered, involving very heavy outlays of money which had not entered into his calculations.

The Shore Section.—The work progressed favorably for over a year. At one point a quicksand made its appearance, requiring the abandonment of a considerable length of finished tunnel. A long curve was made around this obstruction, and all went well again. At a point about thirty-nine hundred feet from the shore, a large and extremely troublesome quicksand was found, which proved a most serious obstacle, and forced the suspension of work at that end. The whole section filled with water and was allowed to remain so for nearly two years, while the excavation was in progress from the other end.

The crib is an immense wooden structure, formed of heavy timbers fastened together in the strongest possible manner. It is pentagonal in form, with a mean diameter of eighty-five feet, each of its five sides being fifty-four in length. This was built on shore, by the

Messrs. Delamater, in the summer of 1870. It was successfully launched and towed out to its resting place, six thousand six hundred feet, or just one mile and a quarter, from the shore. Here it was securely anchored by hundreds of tons of stone, packed in and around it, and to-day it stands as immovable as Gibraltar, the fiercest winds and waves having not the slightest effect upon it. A building made of heavy oak plank, to resist the force of the elements, stands upon the crib. It has been largely occupied by the machinery and apparatus for carrying on the work, but will now be fitted up with comfortable rooms for the occupancy of the "keeper," whose home it will be. It will be readily understood that during the season of navigation a light must be kept upon the crib as a guide and warning to vessels. Although not perhaps in all respects as desirable for a residence as a place on the "Avenue," to an average family, it is not without its partially compensating features.

The Lake Section.—The shaft in the center of the crib was sunk to the distance of ninety feet below the surface of the water. This is some twenty feet lower than the bottom of the shore shaft; but it was found necessary to descend to that depth on account of a stratum of soft clay, through which the tunnel could not be excavated without great expense and danger. The work of pushing the tunnel shoreward was then undertaken with vigor. The proper course was given by the engineer, Mr. Whitelaw, who, as in the shore section, made frequent visits to the tunnel with his instruments for that purpose. Let the reader imagine these two sections, one thirty-nine hundred and the other twenty-seven hundred feet in length, from forty to seventy feet below the bottom of the lake, with the respective starting points a mile and a quarter apart, with a rise of over twenty feet from the foot of the crib shaft, and with sundry curves and turns to avoid quicksands, and he may be able to form some faint idea of the marvellous mathematical skill necessary to bring the ends together, nearly midway between the crib and the shore. It can easily be seen that a deviation "in the estimation, of a hair," at either end, in the vertical or lateral direction, would carry them very far from each other, and the toilers might dig away in there for a lifetime without "making both ends meet." But so exquisitely perfect and accurate are the instruments used, and so masterly the skill and understanding of him in whose hands they were, that the junction was made on Saturday in the most perfect manner. The sections met on an exact level, and when the mason work was finished no person could detect the point at which the connection was made. Although he had implicit faith in his calculations, yet, realizing what must have been the inevitable result of the slightest error, he could but experience a feeling of satisfaction and relief when the miner's pick struck through, and the point was reached where work had been stopped from the other end, nearly two years before.

One million seven hundred thousand brick were used in the construction of the tunnel. These are of the hardest kind, and laid in a cement that when "set" is as hard as the brick itself. The capacity of this tunnel is from sixty to seventy million gallons of water daily. When the fact is stated that the present average daily consumption of water is about six million gallons, it will be seen that the tunnel will be ample to supply Cleveland when it shall have a population of a million.

ON THE SELECTION OF A BUILDING STONE.

By C. A. Evans, Civil Engineer.

This is a subject which has been under the pen of most writers on construction. Yet, notwithstanding this extensive treatment, no general principles have been indicated to direct the selection of a stone for an intended structure. To the engineer, in particular, the selection of materials suitable to the variety of works he executes, is a matter, the importance of which, is of itself evident. It is to elucidate the principles which should guide him in this portion of his labors, that this article has been written.

A continual practice in one direction by reason of some prominent good quality which a stone may possess, often prejudices many builders in favor of the particular class to which it belongs. But an extensive experience in all countries leads to the conclusion that a perfect stone is one which has several good qualities; which is strong, durable, capable of being ornately worked, and of a fine appearance. For engineering works situated in the country, strength and durability are the only points which need be considered. Nevertheless, it is often difficult to obtain a stone which will fulfil even these two requirements. How a stone stands in regard to them, may be determined as accurately as the usual tests admit. No test for durability, however, has yet been discovered which may be implicitly relied upon; yet no known test relating to this point should be omitted by the engineer if he would remove from his shoulders all blame of future *accidents.* A thorough examination of a stone, comprising that of its quarry, of its structure, of its constituents, leads generally to correct results. The plain character of engineering works in the open country, with their architectural effect depending only upon the proportion and disposition of their masses, does not require stones capable of being dressed as elaborately as those for city structures. For this reason this quality does not play here an important role. As regards appearance, it may be remarked, that the surroundings are usually in harmony with it, of whatever color and texture the stone may be. Therefore, even if circumstances did not compel the engineer to employ the most accessible stone, paying attention only to strength and durability, there would really be no necessity to consider anything else. On approaching a large town, however, regard must be had to *all* the foregoing qualities. The class of work now changes. Here are located shops, depots and dwellings. These will be in contrast with other buildings, and show to advantage or not, according to the good or bad choice of their material. The architectural principles which here govern the engineer become more complicated and numerous, and demand, in consequence, a fine stone. Nevertheless, all should not be sacrificed to architectural considerations. Financial matters demand reflection. It would not be wise to draw from distant sources such a stone, when a good one, though inferior in structure and appearance, exists in the neighborhood. In such a case, the engineer must put up with what nature offers him, and employ a style of architecture which will be most in keeping with his material. But in cities a handsome depot demands a handsome stone. If no quarries in the vicinity furnish it, recourse must be had to others more remote. The expense may be considerable, but it must be borne in mind that an ugly material will make a building doubly so, especially if large and surrounded by better architecture. Should a fine stone not be offered, let brick then be used in preference to an inferior one. Some respect should be paid to the requirements of art.

In selecting a stone for an intended structure in a city, we must be governed in our choice particularly by a consideration of the class of onaments which are to appear on the building, and by the expression which it is to possess. If the structure is to be decorated with plain large mouldings of a bold outline, then a coarse grained and dark stone may be used. But should it, on the contrary, be embellished with delicate carvings, or with small figures in relief, either on the mouldings or the plain wall, a light-colored and close-textured stone is required. No dark or coarse-grained stone should be employed in this latter case. For a dark stone will fail to make the shade and shadows of these small ornaments perceptible, thus greatly diminishing their effect. A coarse-grained stone will not admit of fine edges being cut on it, and it is only by such luminous lines that we are enabled to clearly define the shape of the ornaments. For the want of either shade or luminous lines, small figures in relief will often, when viewed from no great distance, appear like lumps raised on the surface of the stone. This is particularly the case after the building has stood for a number of years. On a new building everything is clean. The stones are lighter than the permanent color they will finally assume under the influences of the air, dust and smoke. But the most powerful agent of destruction is the humidity of our climate, under the attacks of which all stones succumb more or less. This is easily perceived on examining their edges. Such an examination will also show that a coarse-grained stone exhibits more plainly the marks of these attacks than a fine-textured one. The particles are comparatively large, and those which are removed leave correspondingly large vacant spaces. Hence it is wrong to carve on such a stone, whatever may be its merits in other respects. Twenty winters will often be sufficient to destroy the edges of ornaments on a coarse-grained stone of great durability. These effects are noticeable particularly when the stone is situated in a place exposed to the prevailing winds and rains, whether in the streets of a city or the open country.

The preceding is a fundamental rule in architecture, yet it is constantly violated. When decoration in a high degree is intended, marble is the most appropriate stone for this class of work. The turn of a leaf carved out of this stone may be distinctly seen placed at the summit of a spire. For the material retains its sharpness of contour, its edges reflect the light, and its shades are visible and effective. In nothing more did that fine race, the Grecians, show their exquisite taste than in the choice they made of this material for their edifices.

Passing now to consider a stone with reference to the expression which its color may communicate to a building, it may be laid down as a general rule, that a light-colored stone is adapted to nearly all buildings, whether of a massive or light, a magnificent or plain character. But structures intended to have a sombre appearance should be built of the darkest stone procurable. Nevertheless, if they are not well designed, the full effect of such a stone will not be brought out.

This material may be used also in combination and contrast with lighter stones, producing quite a picturesque effect. Grandeur of style, however, demands a sameness of color. A medium dark stone gives an air of repose to a building built with it. Still, it should be used either in open situations or in those in which it may receive plenty of light. Hence a narrow street may be considered as an unfavorable situation for its employment.

The finest light-colored sandstones are doubtless those best suited to city purposes. A *good* limestone is also a fine stone in every respect. Some varieties of this stone preserve their color very well. For, being smooth, the dust does not much adhere to them. Many argillaceous stones, on account of their slaty structure, are disagreeable to work, yet they may be advantageously employed. A coarse-grained granite is open to the objections frequently urged against all coarse-grained stones, though some fine-grained varieties, obviating these inconveniences, make fine building stones for moderately decorated structures. But, in general, granites become quite dark with age; and, for close views, as those obtained in a street, they are not, in the opinion of the writer, as effective in appearance as stones the constituents of which are all of an uniform color. For many of the plain works of the engineer, granite may properly be considered as the most desirable material. In basements, particularly in those of depots, it may be introduced on account of its not showing the grease as much as some other light-colored stones. Under the name of granite is here included also that stone known to writers on mineralogy as syenite, and which is especially referred to in the foregoing remarks.

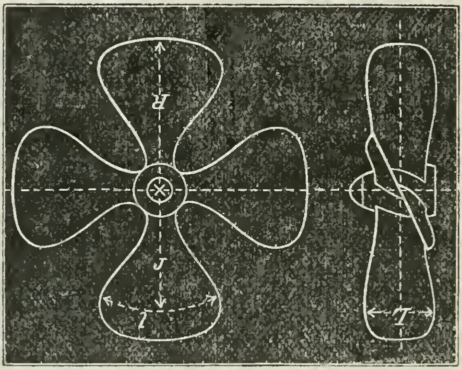
Philadelphia, Oct. 2d, 1873.

St. Gothard Tunnel.—During the month of July the following progress was made at the tunnel: At the west end, at Gœschnen, the length of heading driven during the month was 51 metres, making a total of 259 metres driven up to July 31st. The length of tunnel completely excavated was increased from 150 to 200 metres at that end. At the south end, at Airolo, 47 metres of heading were driven, making a length of 266 metres driven up to the end of July. The length of tunnel completely opened out was increased from 214 to 253 metres. The average number of workmen employed during the month of July was 945, and the greatest number employed at the works in one day was 1159.

ON FRICTION OF SCREW PROPELLERS WORKING IN WATER.

By John W. Nystrom, C. E.

The friction of screw propellers running in water is a considerable item of the propelling power, and is well worthy of attention when speed of the vessel and economy of fuel is desired. The solution of the problem furnishes a good example of the value of the calculus in dynamics.



Notation of Letters.

P = pitch of the propeller in feet.

R = radius of the propeller in feet.

r = any radius less than R.

l = length of a helix for one whole convolution in feet, at the radius r.

A = area of the helicoidal surface for one whole convolution in square feet.

N = number of blades of the propeller.

n = number of revolutions per minute of the propeller.

v = velocity of the helix l in feet per second.

h = horse-power of friction.

f = friction in pounds.

δ = differential.

The friction in pounds per square foot of surface of cast iron and brass, of rough castings and also of smooth surfaces, filed or ground but not polished, is as follows, when the surface moves with the velocity of one foot per second:

Friction Surface.

	f'
Rough cast iron, ...	0·0045
Smooth cast iron, . . .	0·0040
Brass, rough casting, . . .	0·0040
Brass, smooth surface, . . .	0·0030

The friction for rough cast iron will then be, in pounds,

$$f = 0·0045 \text{ A } v^2. \qquad 1.$$

The differential area of the helicoidal surface for one convolution will be

$$\partial \text{A} = l \, \partial r,$$

and the differential friction

$$\partial f = 0·0045 \, v^2 \, l \, \partial r, \qquad 3.$$

when the differential horse-power will be

$$\partial h = \frac{0·0045 \, v^3 \, l \, \partial r}{550}. \qquad 4.$$

The velocity $v = \frac{l \, n}{60}$ and $v^3 = \frac{l^3 \, n^3}{60^3}$. 5.

The differential horse-power will then be

$$\partial h = \frac{0·0045 \, n^3 \, l^4 \, \partial r}{550 \times 60^3}. \qquad 6.$$

Call $\text{X} = \frac{0·0045 \, n^3}{550 \times 60^3} = \frac{n^3}{26{,}400{,}000{,}000}$. 7.

Then $\partial h = \text{X} \, l^4 \, \partial r,$ 8.

and $h = \text{X} \int l^4 \, \partial r.$ 9.

But $l = \sqrt{4 \, \pi^2 \, r^2 + \text{P}^2}$, and $l^4 = (4 \, \pi^2 \, r^2 + \text{P}^2)^2$. 10.

Insert formula 10 in formula 9, and we have

$$h = \text{X} \int (4 \, \pi^2 \, r^2 + \text{P}^2)^2 \, \partial r. \qquad 11.$$

$$(4 \, \pi^2 \, r^2 + \text{P}^2)^2 = 16 \, \pi^4 \, r^4 + 8 \, \pi^2 \, r^2 \, \text{P}^2 + \text{P}^4. \qquad 12.$$

Then $$h = X\int(16\,\pi^4\,r^4 + 8\,\pi^2\,r^2\,P^2 + P^4)\,\delta r. \qquad 13.$$

By integrating each term in the parenthesis we have

$$h = X\left(\frac{16\,\pi^4\,r^5}{5} + \frac{8\,\pi^2\,r^3\,P^2}{3} + r\,P^4\right) + C. \qquad 14.$$

$$\frac{16\,\pi^4\,r^5}{5} = 311{\cdot}71\,r^5, \quad \text{and} \quad \frac{8\,\pi^2\,r^3\,P^2}{3} = 26{\cdot}319\,r^3\,P^2. \qquad 15.$$

Integrate the friction horse-power from the centre of the propeller to the periphery of radius R, then when $r = 0$, $C = 0$.

Insert the formula 7 for X in formula 14, with the values 15, and we have the frictional horse-power for one convolution of the screw and for one side of the helicoidal surface,

$$h = \frac{n^3\,R}{26{,}400{,}000{,}000}\,(311{\cdot}71\,R^4 + 26{\cdot}319\,R^2\,P^2 + P^4). \qquad 16.$$

The helicoidal surface of screw propellers is generally cut up into small portions by a number of blades, each of a fraction of the pitch, and when the helicoidal surface is counted on both sides of the blades, the friction horse-power will be

$$h = \frac{R\,L\,N\,n^3}{13{,}200{,}000{,}000\,P}\,(311{\cdot}71\,R^4 + 26{\cdot}319\,R^2\,P^2 + P^4). \qquad 17.$$

This formula includes both the dragging and rotary friction horse-power of a propeller of rough cast iron.

Call f' = friction in pounds per square foot of surface moving with a velocity of one foot per second, and the friction horse-power will be

$$h = \frac{f'\,R\,L\,N\,n^3}{59{,}400{,}000\,P}\,(311{\cdot}71\,R^4 + 26{\cdot}319\,R^2\,P^2 + P^4). \qquad 18.$$

Example.—Required the friction horse-power of a propeller of the following dimensions:

Diameter of propeller, 20 feet, or . . . $R = 10$ feet.
Pitch, ... $P = 40$ “
Length in the direction of axis, . . . $L = 4$ “
Number of blades, . . . $N = 4$.
Revolutions per minute, . . . $n = 50$.

The horse-power consumed by friction will then be, for rough cast iron surface,

$$h = \frac{0{\cdot}0045 \times 10 \times 4 \times 4 \times 50^3}{59{,}400{,}000 \times 40}(311{\cdot}71 \times 10^4 + 26{\cdot}319 \times 10^2 \times 40^2 + 40^4) = 374{\cdot}528 \text{ horses.}$$

In the year 1850 an experimental steamer was built in Kensington, Philadelphia, which was expected to make 20 to 30 miles per hour. The propeller was about 4 feet in diameter, with only one blade extending the whole convolution of the circle, and with a very fine pitch of about 6 inches. (The author does not remember the exact dimensions). The propeller was expected to make 500 revolutions per minute.

Example.—Required the friction horse-power of the above-described propeller. $R = 2$ feet, $P = 0{\cdot}5$ feet, $n = 500$, $L = 0{\cdot}5$, $N = 1$. Surface, rough cast iron.

$$h = \frac{0{\cdot}0045 \times 2 \times 0{\cdot}5 \times 0{\cdot}5 \times 500^3}{59{,}400{,}000 \times 0{\cdot}5}(311{\cdot}71 \times 2^4 + 26{\cdot}319 \times 2^2 \times 0{\cdot}5^2 + 0{\cdot}5^4) = 95 \text{ horse-power, nearly.}$$

The power of the engine, counted from the size of the steam boiler, did not amount to more than 50 horse-power, and the result was that when the trial trip came off the steamer could hardly crawl up against the tide.

The building of the steamer, was kept in the greatest secrecy, and her performance was expected to astonish the world.

There was another experimental steamer built in Kensington in the year 1864, in which several curious propellers were placed on each side of the vessel, which also turned out a failure on account of the friction of the propellers in the water being too great.

New Reducing Agents.—When water, saturated with sulphurous acid gas, is allowed to act upon zinc powder, the metal dissolves without the emission of gas, and the liquid becomes of a pale yellow color, and possesses, in a high degree, the power of dissolving indigo. Schützenberger has lately been investigating this subject, and finds that this decolorization is the result of reduction. The liquid abovementioned, in its free condition, is extremely unstable; but if a concentrated solution of bisulphite of soda is allowed to act upon the zinc powder, a soda salt of the new acid is obtained, which possesses reducing powers not less remarkable than those of the free acid itself.

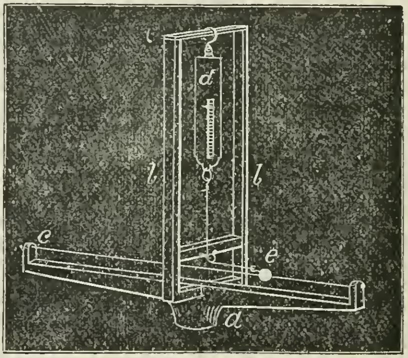
Chemistry, Physics, Technology, etc.

A DEVICE FOR DEMONSTRATING THE LAWS OF THE CENTRAL FORCES.

By Prof. A. E. Dolbear.

The want of definiteness in the conditions under which experiments are usually made with the common turning-table, especially when applied to the demonstration of the laws of the central forces, has led me to devise the following modification of the apparatus for this work. The performance is good, and I therefore submit a description of it, for the benefit of those who teach mechanics, aud especially for those who may study it in any of the various physical laboratories.

The usual form of apparatus for this work, as it is constructed by instrument makers, is too well known to be described here. The subjoined figure will sufficiently well indicate the modification so that any one possessing the common arrangement for raising a weight by the centrifugal force of a ball running upon a wire, can adapt his instrument to it. The frame work *a*, which is screwed to the shaft, has the upright posts *b b*, and the frame *c*, having a wire stretched upon it for the ball, *e*, to move upon. Instead of the usual weights to be raised I substitute a common spiral spring balance, *d*, which hangs from the top bar and is connected to the ball by a stout string tied to its hook, passing round the small pulley at the bottom and thence to the hook upon the ball.



It is evident that when the ball, *e*, moves toward the end of the wire the index of the scale will indicate the number of pounds pull. When the machine revolves the ball is driven outward, and of course pulls upon the scale, which in turn directly points with its index the number of pounds, or, in other words, the centrifugal force. It may be thought that when the scale itself is turning fast the index could not be seen; but, if one stands in such a position that the light from a window or a lamp will be reflected from its face to him, the index and figures can be plainly seen, no matter how fast it goes. The radius of the circle described by the ball, *e*, can be found by adding to its distance from the centre of revolution, when at rest, the measured distance from zero on the scale to the number of pounds indicated. Then, if the weight of the ball itself is known, all the data for the demonstration are had at once. This form will easily permit of graphical construction for the results, which is quite an advantage for a learner.

CONVECTION APPLIED TO THE DETECTION OF HEAT.

From a Lecture on "The Sources of Heat."

BY L. C. COOLEY, PH. D.

I have been thus careful to fully illustrate the production of air currents by changes of temperature in order that I may freely use this principle of convection to make visible to us all the delicate phenomena by which I hope to illustrate the fundamental principles in the science of heat.

Let me describe the instrument by which this novel application is made. You would, no doubt, at first view, pronounce it a form of Coulomb's Electrometer. You observe the slender needle suspended horizontally in this glass case, but you cannot observe the exceedingly delicate silk fibre by which it hangs. This needle is a glass tube. It was made by taking a very much larger glass tube and, in the usual manner, drawing it out to this degree of fineness. It is about four and a half inches in length, and carries a pith ball at one end. This pith ball is blackened—it was rolled in dry lampblack—that it may be more easily seen. The needle, with its pith ball, together with the necessary cement and the varnish which covers it, weighs nearly one and a half grains. Just below the needle is a horizontal disk, the circumference of which is graduated, and the centre of which, when the instrument is level, is exactly in the prolongation of the vertical fibre which sustains the needle. In the cover of the glass case, and just over the zero of the scale below, is an opening through which a body may be thrust when we would bring it into the neighborhood of the pith ball. The motion of the needle will declare the presence of heat or cold. Here is a copper wire which I hold in my hand, and while uttering this sentence I am pressing the end of it gently against my face. Let me thrust it down upon the zero of the disk, the pith ball now standing at 20° away. The needle begins to swing. You see the pith ball slowly approaching the warmed wire; in half a minute more you see the two apparently in contact. Our first impulse is to declare the presence of electricity; our second is to test the truth of such a declaration.

I will join this copper wire by means of this chain to the chandelier which hangs above me, and now, holding it with these wooden pincers, I repeat the experiment. The conducting communication with the earth forbids the accumulation of any electricity in the wire, and yet you see the needle slowly swinging as before. I might make other experiments, if more were needed, to convince you that it is not electrical attraction which moves the ball. It is heat. The scorched air, above a burning temple, rises, while the surrounding atmosphere flows in to feed the flames. In this little instrument you see the action of the same principle in a milder mood. The warmed wire imparts heat to the air in contact with it. This warmed air rises, while that surrounding it on all sides flows in to take its place, and the pith ball is wafted toward the wire by the gentle breeze.

You have already seen the application of heat producing powerful air currents toward the centre of disturbance. Heat and convection are a cause and its effect. Either being sensible, under proper conditions, the presence of the other may with certainty be inferred. Hence convection currents become a test for the presence of heat, or, more correctly, they declare the occurrence of a change in temperature. But the delicacy of this test is, perhaps, greater than our intimacy with convection currents would lead us to expect. Yonder is a beam of sunlight streaming through the window-shutter. I will cut its pathway with a mirror, and thus throw it against the side of the glass case of our thermoscope, directing it upon a point, it may be, 30° away from the pith ball. The beam will warm the glass. We must wait until the heat has passed its thickness. The air in contact with the glass within will then be warmed; convection currents will be occasioned, and the motion of the needle will make them visible. Already the motion of the pith ball can be seen distinctly. Such delicacy as it possesses is, for occasions like the present, an obstacle to its use. Before I can continue my experiments with the instrument, I must wait for the glass to part with the heat it received from the sunbeam. The heated portion of the glass fetters the needle, and prevents its response to the gentler solicitation of other objects. But in the meantime let me turn my sunbeam upon the bulb of an air thermometer. We wait until the thin glass is warmed; still, at our distance we can discover no motion of the fluid in the stem. This sunbeam may be as cold as one of moonlight for aught the air thermometer informs us to the contrary. Doubtless the air within the bulb has expanded ; by a closer examination of the scale I can perceive the degree, but you will no doubt all agree with me that for our purposes, convection is a better detective than expansion.

Placing a copper wire upon an anvil, I raise a hammer to the height of a foot above it and allow gravitation unassisted to pull it down. After the collision I quickly but carefully thrust the wire into the neighborhood of the pith ball. The slow swing of the needle toward it announces to us all that the wire was heated by the blow. The motion of the mass of iron became suddenly a motion of the molecules of copper, and in their thermal tremor is the equivalent of the force of gravitation which brought the hammer down.

I take another similar wire and find, by thrusting it into the thermoscope, that it has no power to move the needle. Let me now press it gently upon the cold table-top and at the same time make a few rapid passes back and forth over its surface. Quickly introducing it to the pith ball, we see the needle speedily spring toward it. The metal has been warmed by the friction. The visible motion caused by my muscular effort in rubbing the wire, became an invisible tremor of the molecules of the metal, and reappears finally in the visible movement of the needle.

Taking another wire, whose temperature has not been disturbed, and which we find unable to awaken any response in the thermoscope, I place the end of it between the smooth jaws of a vise and press it severely by a turn of the screw. Transferring it without delay to the thermoscope, we see the pith ball, by its approach, announcing the evolution of heat by the pressure.

Blows, friction, and pressure are the three forms of *mechanical action*. The three experiments just made are typical. Together, they illustrate the truth, considered demonstrated by multitudes of phenomena in each of the three classes, of which these experiments are types, that no mechanical action occurs without the evolution of heat. Incidentally, these experiments also afford us a set of most beautifully simple illustrations of the curious and facile transformations of motion, so constant and so important in the economy of nature.

I now take two liquids—a thimbleful of oil of vitriol and a fourth part as much of water. I will show you first that the temperature of these liquids is the same as that of the air within the thermoscope.

While still moist with liquid, I plunge these two wires successively into the glass case; the needle responds to neither. But now I mix the liquids, and I plunge a wire into the mixture. Let me next thrust the moist wire into the instrument. See how quickly the needle responds. Its motion toward the wire declares the presence of heat therein.

But what is the origin of this heat? No friction, no percussion, no pressure which the senses can detect. The action is molecular. So strong is the attraction between the molecules of the two liquids that they leap the interval which separates them, and, like cannon balls flying from opposite directions, they strike each other. The collision shatters them, and while their atoms seek a closer combination, this thermal tremor throughout the mass goes on. The almost infinite number of collisions balances the almost infinitessimal value of a blow, and we are able to detect the heat generated by the aggregate percussion with greater facility than we can that evolved by the blow of a hammer.

But notice, it was not the heated liquid; it was the heated wire which the pith ball of the thermoscope approached. The wire received a portion of heat from the liquid and again imparted it to the air within the instrument. But in the light of our philosophy what is this transference of heat? We are taught to consider the liquid and the wire to be in the condition of two bodies in contact, with different rates of motion. The greater velocity will be reduced, and the lesser one increased until the two motions shall be equalized. Were our eyes endowed with more than microscopic vision while the wire is being heated, we could doubtless see a countless multitude of little molecules of liquid swinging against the multitude of more sluggish molecules of metal, and urging them to greater speed.

Such an invisible transfer of motion occurs whenever two bodies of unequal temperatures are brought together. It is easy to detect the loss of molecular movement in the one, as the gain of it in the other. I take this wire and plunge it into ether. It emerges from its bath moist with the liquid. A gentle rise of temperature converts this film of ether into vapor. On simple exposure to air it evaporated. The heat for this purpose is taken by the liquid from the metal and the wire becomes in the same proportion colder. I carefully thrust the wire into the thermoscope, and *the needle swings away from it* as if controlled by a strong repulsion. Announcing the pressure of heat in our former experiments by approaching the wire, it now announces the reduction of the temperature of the metal by receding from it. Picture to yourselves the molecular motion of the wire and of the air which surrounds it. Notice that the thermal tremor in the air is more violent than in the metal, and that it must be, therefore, checked by contact. But this checking of its molecular motion is, in familiar phrase, the cooling of the air. This cold air, heavier than that which surrounds it, responds to the attraction of gravitation, and, falling, pushes the air on all sides away. Air currents from the wire, like the land-breeze from an island at night, are occasioned, and, feeble as they must be, they are strong enough to show their presence. You saw the frail needle of the thermoscope wafted by the gentle wire-breeze.

Thus this tell-tale needle is ever ready to respond to either heat or cold. Careful to protect it from all outside thermal disturbances, we may question it with the utmost confidence that it will declare correctly whether an object is warmer or colder than the air in which the needle is suspended. We are to place it upon the side-table for a season only to have recourse to it again in our future study of other parts of the science of heat. It has silently responded to many of my silent questions, privately, during the two years past, whether to those of any person else, I know not; indeed, I must own my ignorance of the existence of another convection thermoscope.

A NEW OPTICAL TOY.

By Prof. A. E. Dolbear.

While seeking for a method of projecting the phenomenon of manometric flames, I stumbled upon the following interesting and instructive device, which is so easily made and presents such optico-acoustic effects that I thought it worth the attention of every one who is engaged in physical experimentation. That a thin membrane will vibrate from the pulsations of air due to sound-waves has been known a long time, and many interesting experiments have been devised to show this. König's Manometric Flames and Scott's Phonautograph are based upon this property, and are among the latest inventions for illustrating it. They are both rather complex and costly, and can be had but by a few. This apparatus of mine can be made for two cents or less, and with it almost everything that can be shown with the two named instruments can be shown, and more, many of the finest illustrations of tuning-forks, namely, the Lissajous curves, are exhibited on the largest scale.

But to the instrument. Take a tube of any material, from one to two inches in diameter, and anywhere from two inches to a foot or more in length. Over one end paste a piece of tissue paper or a thin piece of rubber, or gold-beaters' skin; either will do. In the centre of the membrane with a drop of mucilage fasten a bit of looking-glass not more than an eighth of an inch square, with the reflecting side outward of course. When dry, take it to the sunshine and with the open end of the tube at the mouth, hold the other end so that the beam of reflected light will fall upon the white wall or a sheet of paper held in the hand. Now speak, or sing, or *toot* in it. The regular movement of the beam of light with the persistence of vision presents very beautiful and regular patterns, that differ for each different pitch and intensity, but are quite uniform for given conditions. If a tune like Auld Lang Syne is tooted slowly in it, care being taken to give the sounds the same intensity, a series of curves will appear, one for each sound and alike for a given sound, whether reached by ascension or descension, so that it would be possible to indicate the tune by the curves; in other words, it is a true phonautograph.

By trial one can find some tone which caŭses the membrane to vibrate in a single plane, and of course a straight line will appear upon the screen. If, while the sound is continued, the tube be swung back and forth at right angles to the line, the sinuous line will appear, which may be either simple, representing a pure and simple sound, or it may be compound sinuous, showing over tones, precisely as in König's manometric flames.

With the lecture room darkened and using the beam of light from a porte lumeire or from a lantern, these may be projected of an immense size. There is no trouble in the world to make them eight or ten feet amplitude or more if needed. At a distance of but three or four feet the curves will spread out to two or three feet in length when a tone is made to which the tube can reasonably respond.

The music that one will make with such a musical instrument will not be likely to find favor among musical critics, for it savors very much of the paper and comb sort, such as the unsophsticated ear of a ten year old boy is fond of, but it may be endured for a few minutes in view of its residual excellencies for illustration and demonstration. It is worthy of a good name in the great scope family, and I christen it Opeidoscope.

AMERICAN MACHINERY ABROAD.

The great industrial exhibition at Vienna is now drawing to a close, and by the time the lines we now pen are presented to our readers, it will have become a thing of the past. Unfortunately, America's part in this World's Fair was, by no means, worthy of her acknowledged position as a manufacturing nation; from all accounts it appears that our industries were but meagerly represented; yet, small as this display may have been, the unusual interest, the practical utility and beauty of many of our exhibits, made the American Department a centre of attraction for all in any way interested in the progress of the mechanic arts. Our claim to distinction in this important division of the world's industry is rapidly becoming established; American thought, American inventive skill, find a recognition and a hearty approval among the educated mechanics of every land. The European engineer carefully watches our progress, and endeavors eagerly to avail himself of our discoveries; thus, although Mr. Corliss did not exhibit a single engine at Vienna, such was the celebrity of his inventions, and so wide-spread their influence, that he was awarded a Diploma of Honor, inasmuch as many of the steam motors displayed by European makers were of his type. This Diploma of Honor, we learn, "was designed to bear the character of a peculiar distinction for eminent merits in the domain of science, and its application to the education of the people and the advancement of the intellectual, social and material welfare of man;" and was awarded "exclusively by the Council of Presidents upon the proposition of the International Jury."

One of the largest and finest displays, in the American Machine Department, was from Philadelphia; and to this we now wish to direct attention—we allude to the machines sent by Messrs. Wm. Sellers & Co. It pleases us to learn that the work of this Philadelphia house has, like the Corliss Steam Engine, been extensively copied abroad, and, what is equally gratifying, that its great practical value has been publicly attested by the same peculiar distinction. The exact words in which the group jury recommended that the Diploma of Honor be awarded, in this instance, were as follows:

ORIGINAL:

"*Sellers.*—Wegen besonders hevorragenden Leistungen in Erfindung und Fabrikation von Werkzeug Machinen, die zum Theil den Constructeuren aller Länder als Vorbilder gedient haben."

TRANSLATION:

"*Sellers.*—For pre-eminent achievements in the invention and construction of machine tools, many of which have been adopted as patterns by the constructors of tools in all countries."

To fully appreciate this award and the considerations that prompted it, we must call to mind that, in the French Exposition of 1867, this house, in common with other American machine-tool builders, displayed a large amount of machinery, which attracted considerable attention abroad and found a ready sale. Commenting upon these tools, Prof. Reuleaux, Director of the Industrial Academy of Berlin, in his report on Motors, Machines and Machine Apparatus, at the Paris Exposition, writes thus:

"Upon the field of inventions and of inventive genius, there were but few highly remarkable achievements present, and among these America held the first rank. Her machine exhibition bore almost exclusively the character of originality, and, although the execution was not generally superior, it contained examples of the highest order of constructive ability and perfect workmanship." "France and England offered less original matter—more than both perhaps Germany and Switzerland——"

"Upon the whole it may be said that in machine industry England has partly lost her formerly undisputed leadership, or that she is at least about to lose it. The healthy young trans-atlantic industry, which continually withdraws from us energetic and intelligent heads and robust hands, makes, with the aid of her peculiar genius, the most sweeping progress, so that we shall soon have to turn our front from England westward."

"Newly devised motors, forming part of complete machines and models of distinct parts, exhibited as novelties or inventions, were numerous. In the first direction Sellers & Co., of America (Philadelphia), have accomplished the most. The constructions of Sellers, some of which have very rapidly made their way through Germany, bear, in regard to invention, the peculiar, unique stamps of American genius. They are distinguished from us by more direct and rapid conception. The American aims straightways for the needed construction, using the means that appear to him the simplest and most effective, whether new or old. Our historically heaped up material and the cautious character of the German are so inseparably interwoven that among the number of known means we often forget to ask whether they are the simplest or whether new ones might not be better. The American really constructs in accordance with the severest theoretical abstraction; observing on the one side a distinctly marked out aim, weighing on the other the already available means or creating new ones, and then proceeding, regardless of precedents, as straight as possible for the object. This spirit is manifest in Sellers' lathes, shaftings and bearings, in his planing machine with diagonal screw shaft, in his screw cutting machine; and it is strikingly prominent in his system of screw threads, which he has boldly placed alongside of the old venerated Whitworth system, in spite of the terror of its numerous adherents, after he had discovered actual deficiencies. A proper valuation of this proceeding contains the most instructive hints for our higher technical institutions."—*Public Ledger, October 4th.*

It will be thus seen that the peculiar originality of design and boldness of execution displayed by American machinery was noted at that time. The comments of the foreign press on the Exposition of 1873 are of a like character; for example, *Engineering* (London, August 29th), under the head of Machine Tools at the Vienna Exposition, speaks as follows: "Leaving the American collection, and passing on to the British section, we cannot but be struck by the different character of the exhibits. In the American department almost every tool possesses some novel feature, and each is distinguished by an individuality which shows it to be the special design of its maker; while in the British section the great majority of the tools are reproductions of the old and well-known patterns, possessing scarcely any interest whatever as exhibits." Describing in detail certain English tools, mention is made of "one of Sellers' planing machines, with the driving pulleys arranged at right angles to the position given to them by Messrs. Sellers themselves, and some Sellers' screwing machines." Regarding this planer we shall have more to say hereafter. Again, in speaking of some Swedish machines, the writer says: "These tools are well made and of good design, but the patterns have a strong appearance of having been, to some extent, copied from American originals. The counter-shaft of the lathe, we notice, is carried by hangers of Messrs. Sellers' type, and in place of shifting the belts, friction clutch pulleys, of the pattern made by the Brown & Sharp Manufacturing Company, of Providence, U. S., are used for stopping and starting. In pointing out these facts we by no means desire to disparage Mr. Munktell's exhibits: the expedients adopted are good, and they deserve to be used in Sweden as well as in America." Although a high order of merit is thus recognized in all the exhibits of American tool makers, the special honor conferred upon William Sellers & Co. leads us to take their work as a prominent example of American ingenuity, and as showing something of the influence it is likely to exert in the world at large. To aid us in considering this subject, we have before us an illustrated catalogue of machine tools, entitled—"A Treatise on Machine Tools as made by William Sellers & Co., Philadelphia." This work, a neat duodecimo, is profusely illustrated by photographs and wood engravings, and contains not only a description of the various machines made by this firm, but also many of their ideas in regard to the use of tools and the general management of shops.

An examination of this book, in connection with the Vienna award to this firm, and the favorable comments of our foreign contemporaries abroad, seems to call for more than a mere passing notice.

To make any machine of even moderate complexity, machine tools such as lathes, planers, drill presses, &c., are essentially requisite. All branches of mechanical industry are dependent upon the machine tool builder for their possible existence, save in the crudest form. Without machine tools, the steam engine and the power printing press would be impossibilities; and without them modern civilization could not exist. In the manufacture of these important tools, America seems—if we may judge from the flattering comments of the foreign press, and the increasing market which American tools find abroad—to be taking the lead, and that apparently because of the peculiar excellence of principle and novelty of design exhibited by American machine tools.

This fact, in view of the greater experience, cheaper labor, and ofttimes better facilities of the European manufacturer, seems, at first, contrary to what ought to be expected; and we are led naturally to ask the reason for such remarkable inventive activity in this particular direction, among American mechanics. A little thought, however, may show us that one of the most important reasons for this may be found in the very fact that with us wages are high and materials costly. Mr. Thos. Brassey, M. P., in his recent treatise on "Work and Wages," shows that in those countries where the working classes are paid the highest wages, the greatest mental effort is usually made to devise mechanical expedients to diminish more or less the necessity for purely manual labor,—not for the purpose of saving the laborer, but to enable each workman to produce more and better work than if unaided by such machines. Mr. Brassey also shows, by numerous examples, that, in spite of the high wages paid to American workmen, the work they accomplish not only costs no more than similar work done in the countries of cheaper labor, but that the actual cost is often much smaller. The true secret of American progress in the domain of tool building is thus really to be found in the great cost in America, of labor and material—a cost so high that it forces the manufacturer who would be successful, to employ to the best advantage every hour of labor, every pound of iron and coal. This fact coupled with American energy and enterprise is sufficient, we think, to account for American success.

Indeed, the very principles and theory of American machine construction bears witness to this; no opportunity is lost to save a useless step, an unnecessary motion. Writers on the subject remark that Americans try to arrange their machines so as to make them the most convenient for the workman. The planing machine for iron made by Messrs. Wm. Sellers & Co. is one of the tools that attracted the most attention abroad, and in referring to their book we find the following, in a description of this machine, extracted from the "Practical Mechanic's Journal," London: "Most conspicuous and important among the various novel features of this machine is the manner of giving motion to the table. This is furnished with a rack, but instead of being operated by the ordinary spur-gearing, it receives motion through a peculiar form of spiral pinion upon a driving shaft which crosses the bed diagonally, and passes out in the rear of the upright, on the *side where the workman stands.* (The italics are our own. Ed.) This shaft is driven from the pulley shaft by means of a bevel wheel and pinion. The position of the pulley shaft *places the driving belt within convenient reach of the operator;* and its axis being parallel with the line of motion of the table, these machines may be placed parallel to lathes, and thus economize space and permit a better arrangement of the workshop." In noticing the Sellers' planer reproduced by an English house, as mentioned in our extracts from "Engineering," it is further said, it has the pulleys arranged at right angles to the "position given them by Messrs. Sellers themselves."

Nor is this all; one of our correspondents, an active member of the Franklin Institute, just returned from abroad, tells us that the pulleys are not only placed at right angles to the line of motion of the table, but on to opposite side of the machine, entirely out of reach of the workman. Struck with this apparently unaccountable change, he at once inquired its reason, and was told that the pulleys were so placed because British workmen *were used* to having pulleys put in this position. Here we see a clearly demonstrated advantage in an American invention set aside, as it seems to us, to satisfy the unthinking prejudice of the so called "practical workman." These workmen's prejudices always retard progress, and we fear are more likely than anything else to prevent a full appreciation of the spirit of American inventive genius in lands where tradition rules.

That American machine tools should be copied in countries where the art of tool building had its origin must be gratifying to their inventors; but if with these tools the spirit of enterprise of the American workman and his readiness to adopt all labor-saving contrivances could be carried abroad, no little good to the world at large might be accomplished. This, however, must be a work of time, so radically opposed is the American system of well-paid, intelligent workmen to the English policy of cheap labor and forced ignorance—a policy that urges the reduction of wages to that minimum which will just enable the unmarried workman to procure the bare necessities of his cheerless existence.

Accounts continually reach us of the difficulty of introducing labor-saving machinery where labor is cheap and laborers ignorant.

If in our own land necessity compels the invention of labor-saving machinery, so does necessity compel its use; the labor element of population is not sufficient for the wants of the country, and the introduction of these aids to industry does not deprive a single man, woman or child of employment; but, on the contrary, it renders possible the utilization of unskilled labor, in the higher branches of mechanical art, at more remunerative wages. This seems to us happily expressed in Messrs. Sellers' book, in their treatise on lathes (page 69):

> "It has been said that good workmen can do good work with poor tools. Skill and ingenuity may indeed accomplish great results; but the problem of the day is not only how to secure more good workmen, but how to enable such workmen as are at our command to do good work, and how to enable the many really skillful mechanics to accomplish more and better work than heretofore; in other words, the attention of engineers is constantly directed to so perfect machine tools as to utilize unskilled labor."

While we regret that American industries were not better represented at Vienna, we feel gratified at the praise bestowed upon what was displayed, and are justly proud of the prizes awarded to members of the Franklin Institute.

THE UTILIZATION OF COAL WASTE.*

The waste culm, or slack, as it is variously called, that accumulates in coal mining, has long presented a problem to economists and inventors. Great hills of this material arise wherever coal is brought to the surface, and these dingy hummocks have become as familiar a feature of Pennsylvania scenery as the wavy outlines of the tree-clad Alleghanies. The mountains of waste, moreover, are constantly growing, and their present cubic contents are estimated by hundreds of thousands of tons. As yet they simply represent labor lost. The best coal being in general more brittle, furnishes a larger quota to the waste heap than the poorer varieties, which are comparatively either soft or stony. In a recent paper read at the Bradford Meeting of the British Association for the Advancement of Science, Dr. Siemens, the well known inventor of the Regenerating Furnace, states the amount of coal left behind at the mine as waste, in English experience, as 20 per cent. of all that is extracted.

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* New York Tribune.

Inventions usually run in grooves. There have been many patents taken out, and a very considerable number of processes actually introduced in Europe and this country to utilize coal waste, but they can mostly be classed under two heads: (1) Burning the waste in a hot blast; (2) mixing it with some adhesive material and forming it into lumps. The first of these processes is, of course, only available in certain manufacturing operations. It requires for complete success the further reduction of the waste to an impalpable powder, and otherwise than experimentally has rarely been attempted. It is with the second class of processes that we have to deal. They have met with more success abroad than here, partly because employed with bituminous coal, and partly because the cost of labor and of adhesive materials proves with us a most formidable obstacle. In some European processes adhesion is obtained by mixture with gluten. Starch is named in one of the Belgian processes. Coal tar or its derivatives are specified in a large proportion of the patented mixtures. Rosin is used in one and shellac in another process, each of which has received commendation. Tan bark, saw-dust and peat are among the substances not unfrequently added, to give bulk and to make the compound readily inflammable, and as thus prepared its use is advocated for kindling as well as for fuel.

There is on exhibition at the Fair of the American Institute in this city the model of a machine for producing an artificial fuel belonging to this general class of inventions, but which in many respects surpasses anything hitherto devised. Most of the processes successful in Europe with bituminous coal fail here when applied to anthracite. The former supplies, when fired, a certain amount of bitumen, which helps to hold the artificial lump together until it is coked, while with anthracite the binding material, if inflammable, is soon burnt out, and the lump falls to pieces, dropping through the grate before the coal is consumed. If, on the other hand, an incombustible adhesive material is employed it may occasion a new difficulty. Silicates have been tried, but they form slags and clinkers by their fusion. The binding material of the invention under consideration is neither combustible nor fusible. This material is clay. So far, however, there is little novelty, for the use of clay has not been unusual in these mixtures, but it has been in general combined with resinous or bituminous materials, its shrinkage in heat being set off against their tendency to swell. But in those inventions it was necessary that the coal be washed, dried and heated, and the cement kept liquid by heat. As, when such fuel was used, the cementing material gave off smoke and bad odors, a further process was found necessary to expel the volatile portion of it by carbonization or coking. It will easily be perceived that all this added largely to the expense of the artificial fuel. The process before us dispenses with the use, for adhesive purposes, of bituminous or resinous material. The only cement used is common yellow clay, with the addition of some milk of lime; *i. e.*, water carrying five per cent. of lime.

At an earlier period in the history of this invention it was scientifically tested by the Committee on Science and Arts of the Franklin Institute, Philadelphia. At that time, the inventor, Mr. E. F. Loiseau, of Mauch Chunk, Pa., added to the waste about seven per cent. of clay; he now uses but five. His fuel was then compressed in cylindrical molds; he has since improved its form. But the other features of the process, the use of the milk of lime, and the waterproofing of the surface of the lumps by immersion in a solution of rosin, remain unchanged. The report, dated December 19, 1871, is exceedingly favorable. Samples immersed in water for twelve hours, when broken for examination were found dry in the interior. Comparisons were made with a moderate and also with a strong draft. The percentage of ash was somewhat larger than with ordinary fuel, but was of a heavier and more cleanly character. The artificial fuel made with anthracite waste evaporated on the average to one pound of fuel 6·85 pounds of water; the average for pure anthracite is one pound of coal to 7·40 pounds of water. One pound of artificial fuel made of bituminous waste evaporated an average of 10·99 pounds of water; the average for bituminous coal is 14·88. The ability of the artificial fuel to endure transportation was then estimated as not equal to the best of coals, but superior to many varieties brought to market. The cost of manufacture at the mines was at that time about $1 per ton; it is now 85 cents. One day last week a considerable quantity of this fuel was thrown into the furnaces of the main boilers that supply engine power for the Fair of the American Institute. The intention was merely to exhibit its general characteristics. Each lump being varnished with rosin, it could be handled without soiling the fingers. It burned steadily, holding its shape without disintegration, till reduced to ashes.

The machinery for manufacture as exhibited in the model dispenses enrirely with handling the materials. The clay is poured in through one hopper, the coal-dust through another, the substances falling into equally revolving partitions on two separate shafts, the partitions that take the coal waste receiving and delivering exactly nineteen times as much as those that take the clay. As the coal and clay fall together they are sprinkled with milk of lime, which the machinery delivers in due proportion. The moistened mass is carried by a screw propeller into the mixing machine. Careful study of previous inventions and a long course of costly experiment had convinced Mr. Loiseau that many previous failures had been due to imperfect mixing. In this machine seven upright shafts, each carrying four toothed arms, cross one another, moving in different directions, and effect a thorough mixture. There is a very ingenious contrivance by which each shaft can be lifted and cleared without displacing the rest, in case a stone or other obstacle chokes the machine. The plastic product is forced thence by a series of knives and a screw propeller arranged on a central shaft, giving a pressure of several tons to the inch, through an aperture, upon molding rollers which receive it in ovoid cavities. From these the lumps are delivered in shape and size like hens' eggs. This shape was adopted as the result of many considerations and experiments. The lumps had been made in cubes, but these falling together with flat surfaces in the furnace did not permit free passage of air between them. A similar though less forcible objection was urged against cylindrical forms. The egg shape gives the greatest possible spaces between the lumps.

It should be mentioned that there are simple but effective contrivances for enlarging or diminishing the aperture of delivery to the molds. Leaving these, the lumps are carried on an endless belt into the drying chamber, where the belt revolves over rollers which reverse its direction and turn the lumps over several times, until, at length, sufficiently dried but yet hot, they are dropped into the buckets of an elevator and lifted to another endless belt, which carries them into a bath of rosin dissolved in benzine. Several mechanical difficulties in the process of a minor character are here avoided by devices which we have not space to describe. The heat of the lumps assists largely in evaporating the benzine as they issue from the bath, and the drying is completed by passage on another endless belt in a box where a blower gives a powerful current of air, and where the lumps are carried back and forth and turned over as in the first drying chamber. From the blowing box the finished lumps are discharged by a chute to load cars brought beneath it, the chute holding the load as it accumulates until the car is ready to receive it. As we have said, from first to last no handling is required.

It would be a narrow view of this new industry to perceive in it only the prospect of enriching its painstaking and persistent inventor. The utilization of waste products adds to the wealth of the entire community. Especially is it a matter of interest where fuel is concerned, whose cost is not only an element in almost every manufacturing and commercial enterprise, but enters into the economy of every householder. While the industrial organization of England is shaken to its centre by an advance in the price of coal, we cannot contemplate with indifference an undertaking which promises to cheapen it in this country.

Franklin Institute.

Proceedings of the Stated Meeting, September 17, 1873.

The meeting was called to order, with the president, Mr. Coleman Sellers, in the chair.

The minutes of the last meeting were read and approved.

A proposed amendment to the minutes of the meeting held last May was read, and, upon motion of Mr. Cartwright, it was resolved to insert the same in the minutes of the September meeting. The following is the amendment in question, which refers to the subject of a discussion concerning the Committee on Science and Arts: "Mr. Orr rose in reply to Mr. Briggs, and in opposition to his proposition, he stated what he conceived to be the leading purposes of the Institute, and that he did not consider one of these to be the task of determining whether the inventions submitted to it were actually 'patentable' or not, but whether such were useful and creditable, in accordance with the spirit of him whose name it bears—the great utilitarian of his age. He appealed to the members to judge of the Committee of Science and the Arts from their own knowledge of its services, and closed by moving the indefinite postponement of the motion to abolish it, which was promptly seconded.

"Mr. J. C. Cresson then gave a lucid statement of the activity of the Committee through its career of forty years, specifying a few instances of its marked value, and emphasizing the peculiarly fair and catholic character of its construction, and giving it his unqualified approval. In closing, he requested Mr. Orr to withdraw his motion to indefinitely postpone, in order to permit a direct vote on the proposition of Mr. Briggs, which, being complied with, the motion in question was lost."

The Actuary then submitted the minutes of the Board of Managers, and reported that at their stated meeting, held September 10, 1873, donations to the Library had been reported as follows:

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At the conclusion of Mr. Orr's remarks, Mr. Heyl described the mechanical construction of the invention, and illustrated its practical character, by setting in operation one of his machines, which had been brought into the hall for inspection. The description of Mr. Heyl and the operation of the machine attracted great attention on the part of the members.

Mr. Orr was followed by Mr. George D. Coleman, with a paper on a new system of Ærostation. The speaker described at length the construction of an improved aërostat, of the Montgolfier system, and gave the details of dimensions of one of the machines, which was in course of completion for the Evening Herald newspaper, of Philadelphia, with which it is designed to attempt the transit of the Atlantic.

A paper was read by Mr. John W. Nystrom on Dynamics, in which the speaker called attention to the want of certainty and accuracy existing in that science, and defended his own views upon the subject. On the conclusion of the paper, the speaker made the following motion, which, being seconded, was thereupon carried, to wit:

Resolved, That a committee be appointed by the Franklin Institute for the purpose of establishing precision to the meaning of dynamical terms, and to select and approve such terms as may be found proper, and reject those which they consider unnecessary.

The President thereupon appointed the following gentlemen to serve upon the committee: John W. Nystrom, chairman; J. Vaughan Merrick, L. G. Franck, George F. Barker, Fairman Rogers, and John H. Towne.

The meeting was thereupon adjourned.

William H. Wahl, *Secretary.*

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FOR THE

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VOL. LXVI.] DECEMBER, 1873. No. 6

EDITORIAL.

ITEMS AND NOVELTIES.

The Pulsometer.—The plate herewith shown, represents respectively perspective and sectional views of a novel machine for elevating water, designated by the above name, and which has of late attracted much attention on the part of the technical press of the country. To indicate the novelty of its construction, it is sufficient to say that it is a steam pump, operating without cylinder, piston, piston-rod, stuffing-boxes, glands, cams, excentrics, slide-valves, cranks or fly-wheels; but, on the contrary, is a construction in which steam and water are brought directly in contact, in certain chambers where the alternating vacuum and pressure exerted by the steam is simply utilized to lift and force the water by a species of pulsating action.

The internal construction of this curious apparatus may be understood upon inspection of the sectional view (figure 2), from which it will be seen that it is composed principally of two chambers, A A, of bottle shape, joined together side by side, with long tapering necks, bent towards each other and uniting at S, forming a common upright passage, into which a small metal ball is fitted, so as to oscillate with a slight rolling motion between the seats formed in the junction, thereby preventing the entrance of steam into whichever passage it may fall. These chambers are also connected, at their lower ends, with the vertical induction passage, D, through circular orifices, in which spherical shells are seated and arranged to roll up and down with a limited range of motion, and thereby act as induction valves to the chambers A A respectively. A delivery passage, common to both chambers, is also provided at *h*, as shown in dotted section in fig. 2, and in full in fig. 1. This delivery passage also contains a spherical shell or ball, which oscillates from side to side, between seatings formed in the entrance to the passages leading into chambers A A, and acts as a delivery valve to each alternately. B represents a vacuum chamber, formed between the necks of chambers A A, and is connected with the induction passage through a downward extension (not shown) on the side opposite from passage *h*. *b b* represent flanges covering openings in the bottom of chambers A A, arranged to facilitate the removal of the shell valves when necessary. These flanges have studs or guards cast on their inner faces, to confine the shells to their proper range of motion. The entire apparatus, with all its chambers and passages, is cast in one piece, and at the same time with the induction shell valves in their proper positions, thereby forming their respective seats; while chills of suitable form are placed so as to mould the seats of the steam and discharge valves also. Stud bolts are also cast in their proper positions on all the flanged passages, ready for the screwing on of the flanges.

Steam being at the requisite pressure, and the suction pipe and chambers filled with water, the pulsometer is ready to operate. Now, if steam be admitted into the passage above the little ball near the top of the pump, it will pass into whichever chamber the position of the ball permits, and as the steam enters the chamber directly above the water, and in a manner to secure the least amount of condensation, presses upon the water therein, and forces it out past the discharge ball-valve, and out through the discharge-pipe, to any point desired, with a force equal to the pressure of the steam in the boiler operating it.

Now, when the steam has expelled the water as above described, and the water line has finally become depressed until the upper edge of the water outlet therefrom becomes exposed to the steam pressure, the steam which has filled the chamber suddenly escapes through this water outlet and, mingling with and suddenly agitating the water, instantly condenses, and, owing to the peculiar form of the outlet and its relation to the contiguous chamber, the steam not only escapes

Fig. 1.

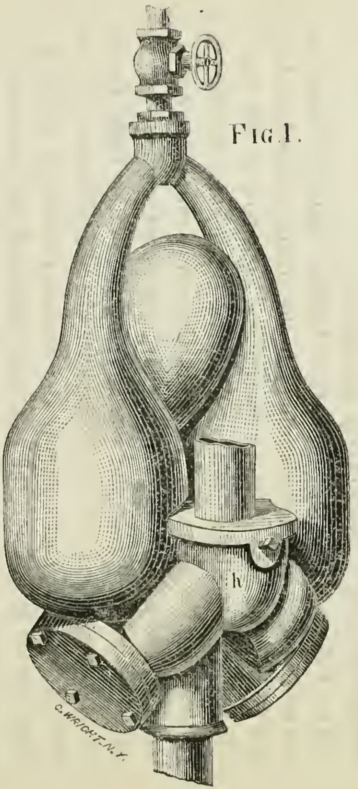
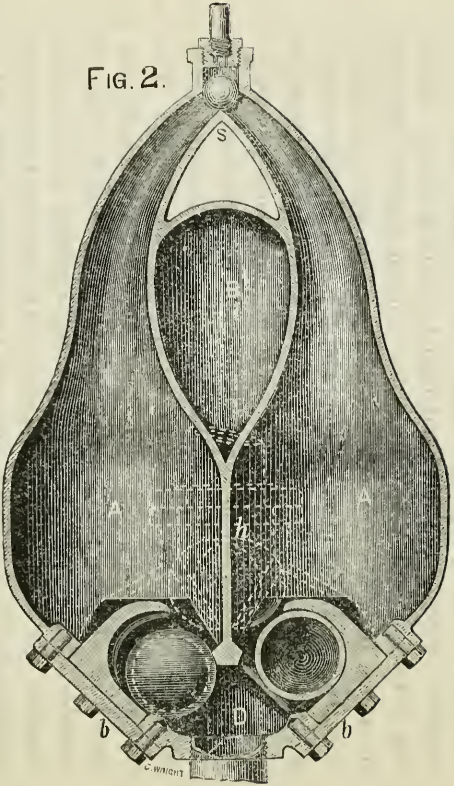


Fig. 2.



THE PULSOMETER.

instantly and condenses, but a nearly perfect vacuum is also produced therein. The ball at the junction of the necks of the chambers (as shown in fig. 2) has been placed in its right hand seat, and, having a limited range of motion, it rests at a point from which it is drawn with the slightest impulse towards its left hand seat. Now, while steam is entering the left-hand chamber with a steady, uniform flow, this little ball will keep the position shown, because the pressure of the steam from above tends to hold it against each seat alike, consequently it remains in whichever seat it is first inclined towards; but as soon as the sudden collapse of the steam by condensation takes place the consequent rush of steam to fill the vacuum instantly unbalances the equilibrium of forces which held the little ball, and it is instantly drawn from its right-hand seat into its left-hand one, and stops the further entrance of steam into the left-hand chamber. The steam current then enters the right-hand chamber and expels the water therefrom also, in the same manner as described for the left-hand chamber. But while the water is being expelled from the right-hand chamber, the vacuum just produced in the left-hand one causes it to immediately fill with water through the induction pipe, and past the ball-valve near the bottom of the chamber, which freely rolls up and out of its seat, permitting the water to freely enter, but instantly falls back to its seat when the chamber is full, prevents the return of the water, and is then ready for the succeeding round of operation as first above particularly described.

The ball-valve in the discharge chamber simply vibrates between its two seats, in a manner similar to the steam-ball before described, and by its alternation simply checks the back flow of the water after it has been expelled from the chambers. The same vacuum impulse which draws the steam-ball towards the upper entrance of the chamber, also draws the ball in the discharge chamber towards its seat, and thereby always leaves the passage for the water from the emptying chamber open. The intermediate chamber shown at B connects directly with the suction pipe, and contains air in its upper portion, which serves to cushion the ramming action of the water as it rushes up the suction-pipe to fill the vacuum alternately formed in the chambers respectively. A small air check-valve is screwed into this vacuum chamber, which lifts when a partial vacuum is produced in the chamber, and allows a little air to enter, but closes against its return. It will open at each pulsation, and its lift; consequently the quantity of air entering the chamber may be regulated by a little milled nut, the operation of which will be readily understood.

Owing to the peculiar form of the large chambers, the steam on its entrance comes in contact with a small surface of water only, which gradually expands as the surface is quietly depressed, thus securing freedom from agitation of water surface, and thereby condensation of the steam, until the discharging outlet is reached by the steam, when instantly the agitation necessary to accomplish the condensation of the steam takes place, and the vacuum is produced as above described. This simple combination of rigid castings, with these four balls, gives all the elements of a double-acting steam pump, having two chambers, which fill and empty alternately, thus drawing and forcing water at the same time. The conditions upon which the proper action of the pulsometer depends are similar, in all essential particulars, to those which pertain to the management of the ordinary double-acting steam pump. It may be placed above the source of supply, a height due a vacuum, and the height to which it will elevate the water is limited only by the presence of the steam in the boiler operating it.

Of the advantages claimed for this device by its inventor, C. Henry Hall, of New York, and the uses to which it may be advantageously put, the following statement will suffice:

It is claimed to be excellently adapted for pumping water from mines, inasmuch as it is not liable to derangement or injury from grit, sand, &c.; also, that it has proved itself of great value in digging foundations and excavating where quicksand or mud occur, pumping the water charged with such impurity without damage; also, that it is adapted for irrigating lands, draining swamps, &c., filling tanks at railroad stations, and for service on shipboard either as a bilge-pump, deck-pump, or fire extinguisher. In brief, it is claimed that the apparatus may be economically and satisfactorily employed under all conditions where water, free from or charged with sediment, is to be pumped, and that the water may be raised to a great perpendicular height, with a comparatively low pressure of steam, by placing a number of the pulsometers above each other, and connecting the discharge pipe of each with the suction pipe of the one above.

An Automatic Railway.—At the stated meeting of the Institute, held Nov. 19th, 1873, Mr. C. W. Hunt, of New York, read the following paper on an automatic railway of his own invention:

The importance of moving and storing coal, ore, or other bulky materials, cheaply, is so generally recognized that the advantages of this railway will be readily appreciated.

The automatic railway is not an improvement or modification of any existing railway, but differs from all, in using the momentum of the loaded car to return the empty car to the loading station.

A large portion of the coal and ore mined is carried the whole or a part of the distance from the mines to the consumer in boats, and when unloaded must, in most cases, be carried back from the bank of the river or canal to the bins or sheds for storage. This is the special function of the automatic railway.

The chief peculiarity of this railway consists in the utilization of the momentum acquired by a loaded car descending an inclined track to return the empty car to the place whence it started. Its advantages are that, without steam or horse power,—

1st, it has three times the capacity of any other method of handling coal or ore.

2d, the running expenses are the wages of one man only.

3d, simplicity.

In unloading coal from boats, it is hoisted by any method and dumped in the car. When filled, the car is started and runs down the inclined track by the force of gravity, deposits its load and is rereturned to the loading point by a weight which the car had raised before the load was discharged.

After loading, the workman starts the car, but does not accompany it down the inclined track; in thirty seconds it has deposited its load in the bins, 150 feet distant, returned and ready for another load. If the car is loaded in 30 seconds, it will be handling coal at the rate of 60 tons per hour, or 600 tons per day, which is about double the amount that can be shoveled and hoisted. The railway is in operation only 30 seconds to each ton; whatever time is taken beyond this is for loading. The whole length of the road is available for storage, as the car dumps the load at any point desired.

Although the capacity of the railway is three times that of any other, yet the operating expenses are far less, as only one man is required in any case. Manufacturers or coal dealers, piling their coal on the end of the dock, require one man on the pile to dump the buckets as hoisted; by using the automatic railway the coal can be carried to any part of the track without any extra expense whatever, as the same man who dumps the buckets also attends the railway. It will cost no more to store coal in the bins 200 feet from the wharf than to dump it on the end of the dock.

This railway is so simple and automatic that an ordinary laborer only is required. There is but one track, 18 inches gauge, and one car; there are no loose pieces to get lost or stolen; after using, nothing to take care of or put away; the car is left just as used, and is ready for use at any time.

The reacting weight can be placed at any part of the track, and be boxed in, as it requires no attention whatever.

The car used dumps the load at any part of the track required. The bottom is inclined each way from the centre, and the sides hinged near the top of the car. The sides are fastened, not to the car, but to each other, holding the car between them, making it impossible for one side to open and not the other. When the sides are opened the coal runs out on either side of the track.

The car is built in the best manner, and weighs 500 lbs. It has 15-inch wheels, Jones & Laughlan's "cold-rolled piston-rod" axles rubber springs, self-adjusting anti-friction bearings and iron-lined bottom. The rope used is Garnock, Bibby & Co. steel; the sheaves have patent roller bearings, requiring no oil. No effort or expense is spared to make this railway the most perfect as well as the most economical railway for yard purposes in existence.

A Combined Heating and Ventilating Apparatus. (Patent of Geo. R. Barker.)—In vol. lxv of the "Journal," page 292, there was illustrated and described a device of this kind, invented by Mr. Geo. R. Barker, a member of the Institute. The essential features of the device consist in the fact that the heating and ventilation are both effected through the same flue, by the insertion therein of a supplementary flue or pipe, dividing the register face into two halves, through the upper one of which the fresh heated air from the furnaces enters the room, while the vitiated and cooled air is drawn out of the room through the lower partition. The apparatus, above described in brief, is designed for the vertical registers located about the sides of the apartments.

The arrangement herewith illustrated is a modified form of the first described apparatus by which the same is made applicable to the floor of an apartment in such a manner that, while the hot fresh air is passing up through the floor, the vitiated air is caused to flow down through adjustable openings, situated immediately surrounding the place of entrance for the heated air, into a suitable conduit pipe leading to the chimney or other flue below the floor.

Figure 1 gives a vertical section of the arrangement. The heated air passes upwards from the furnace through the hot-air pipe, C, which is surrounded by a casing, A, extending some distance beneath the floor, leaving an annular space, A A, about the hot-air pipe, which serves as the egress space for the vitiated or cold air.

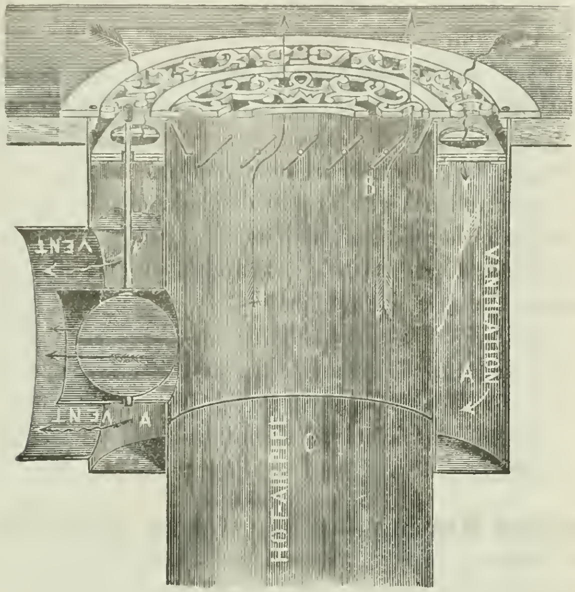


Fig. 1.

The register face is also of annular construction, to correspond with the functions of the several parts of the contrivance over which it is placed. (The figure 2 shows its construction). The openings governing both the ingress and egress passages are controlled by the usual mechanism of an adjustable grating.

The vitiated air which is drawn from the room downward into the annular space A, passes off, in a lateral direction, into a pipe commucating with the ventilating flue.

In the device described in the May number of the "Journal," before referred to, there was an adjustable valve in the upper part of the hot-air pipe, whereby either a portion or all of the heated air rising therein may be discharged into the vitiated air-flue, the object of said attachment being to afford a means of relieving a room whenever, as for example when crowded, it shall become excessively hot, or the air very impure.

The same result is provided for, in the modified arrangement here described, by inserting into the side of the hot-air flue, C, a short pipe (see figure 1), which is made to extend some distance into the conduit pipe. This is fitted with an adjustable valve, whereby the hot entering air may be turned either entirely or in part into the vitiated air-flue whenever it is desired to regulate the warmth of the room above the floor.

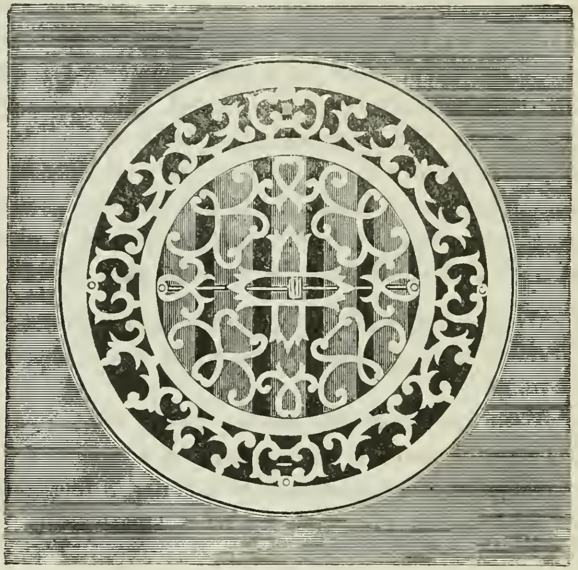


Fig. 2.

The device is, of course, equally applicable to any form of heating apparatus elevated above the floor, with the same merits of simplicity and efficiency possessed by the original apparatus before alluded to.

The Hoosac Tunnel.—The approaching completion of this important undertaking affords at present a theme of comment on the part of the technical press of the country. It is now announced from reliable sources that the work, including the laying of the permanent way, will be fully completed by the 1st of July, 1874. From the monthly reports of progress furnished by the contractors, which are from time to time published, the work of pushing forward the headings has progressed favorably and uninterruptedly for some time, there remaining on the first of November only about one hundred feet of rock to be pierced. Before the close of the month, therefore, there is every probability, unless some unforeseen accident intervenes to interrupt the average progress of the tunnelling work, that the two headings will meet.*

From a contemporary† we take the following comments:

The Hoosac Tunnel is four and three-quarters miles long, twenty-four feet wide by twenty-six feet in height. The rock through which it has been pierced is of a very indurate character; so much so as to render the work considerably more difficult than that of the Mont Cenis Tunnel, which is, however, seven miles long. The central shaft is 1030 feet deep. The work was commenced in 1850, and, after having been several times abandoned and recommenced, the present contractor made an agreement, in 1869, to complete it within five years. Undoubtedly the success of the work has been greatly dependent upon the use of steam drills and improved blasting explosives; nitro-glycerin has also been largely employed, and most of the drilling has been performed with the Burleigh rock-drill.

The Fireless Locomotive.—The Chicago "Times" gives the following account of the fireless locomotive in use on the tramways of that city:

In front of the cars was the motive power, contained in a small, compact and neat locomotive, manipulated by an engineer. This was the fireless locomotive. It consisted of a boiler, 8 feet long by 3 feet in diameter, and the usual machinery on a small scale. There was no fuel, no fire, no fireman. The steam was supplied for the round trip of six miles before starting. At the depot was a supply boiler, 16 feet by 3 feet, in which steam was generated until 200 lbs. pressure was indicated by the steam gauge. The locomotive boiler was three-fourths full of cold water. Instead of boiling this by means of a fire, and raising the pressure to a required height, the steam was introduced from the supply boiler through an iron tube. The iron tube was connected with the locomotive boiler, the latter running under the water, along the bottom of the boiler, and letting out the steam as it was freed from the supply boiler into the locomotive boiler. This steam, rising through the cold water, permeated it, and quickly raised its pressure to 170 lbs. With this supply of steam the locomotive started, drawing a heavy four-horse car, over three miles, to Thirty-fifth street in ten minutes.

The amount of steam consumed represented 80 lbs. pressure, locomotive starting back with 90 lbs. remaining. When the starting point was reached there were 57 lbs. of steam in the boiler, the pressure being reduced only 33 lbs. in return trip, which was a down grade. It must be borne in mind that there was a large car, heavily laden, making 18 miles per hour. The experiment proved conclusively that, as a substitute for dummy engines, the fireless locomotive is, beyond question, a success. No fire or fireman are necessary, very little steam escapes, and the locomotive, not being one-half the size of the clumsy dummy engine, does not frighten horses and endanger the public safety.

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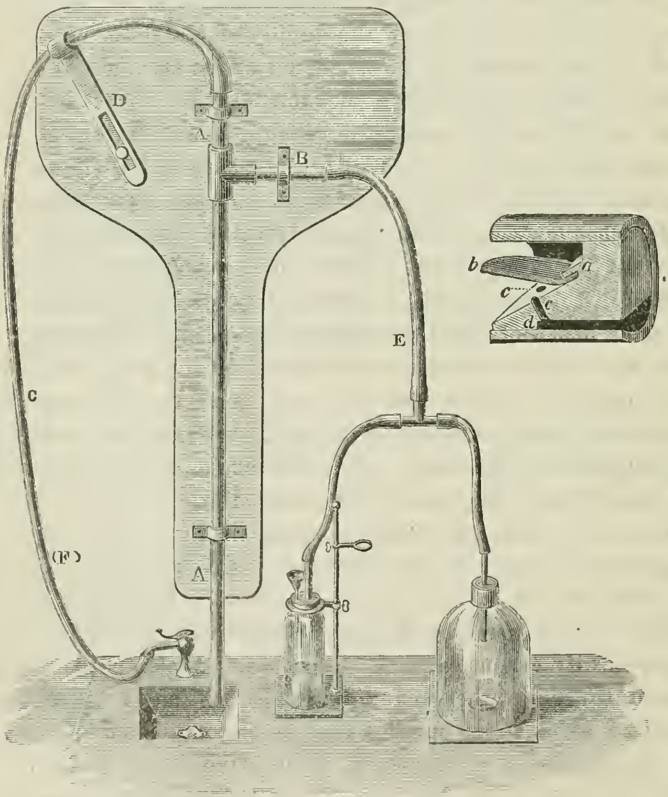
*The headings met on Nov. 24th, and the tunnelling work is complete.

† Am. Artisan.

On a Modification of Jagn's Filter Pump.—By Prof. A. E. Foote.—The general introduction of the Sprengel vacuum pump, since its modification by Bunsen, has been somewhat interfered with by the difficulty, in some cases, of securing the required fall of water. The pulsating pump of Jagn, to a great extent, obviated this difficulty, rendering it possible, from a fall of from four to five feet, to



produce a tolerably good vacuum. Many inconveniences, however, have been experienced by those adopting the device indicated by Jagn and others, the most troublesome defect residing in the caoutchouc valve, which very soon becomes imperfect or inoperative.

The accompanying illustration represents a form of construction devised by Prof. A. E. Foote, and is fully described in the Am. Jour. of Science (November, 1873). The device is stated to be simple in construction, to be free from the objections attaching to those above named and to give very good results. The following is a condensed description of the apparatus: A, A is a tube about four feet long, and from three eighths to one inch in diameter. To the side of this is attached an arm B by a T coupling. B is from four to eight inches long, and may have a manometer attached. C is the caoutchouc vibrating tube, which conducts the supply of water to A. The upper part of A, over which C is thrust, is cut off at an angle of 40°. The vibrations are controlled by a movable arm D. To B is attached a rubber tube E, which leads to the vacuum flask. Within B, and near its connection with A, is fixed with cement the valve shown in fig. 2, constructed as follows: A cylindrical metal plug, about one inch long, and of such dimensions as to slip easily within the tube B, is cut away at one end (as shown in fig. 2, where it is represented in section with a portion of tube B) leaving a tongue of metal. This tongue is driven down upon a flap of sheet caoutchouc about one millimeter in thickness b, which is thus held upon the bevel of the plug, and covers the two channels c c, one of which is seen in section. These channels communicate with passage d, made by filing away the metal of the plug tangentially (see cut). The caoutchouc flap is represented as lifted away from the face of the plug, in order to show the orifices which it closes when the water current in the tube B is checked. These holes, in order to be perfectly closed by the flap, must be at least one-sixteenth of an inch in diameter. The sheet caoutchouc should be thin as possible, to insure perfect action. This plug must be hermetically cemented with the tubes. A clamp placed upon E, and used to retain the vacuum, may also be made to regulate the rapidity of exhaustion, but this may be accomplished more conveniently by means of a stop-cock, F, inserted in C, which regulates the flow of water; or, by means of a "globe-valve" placed in the supply pipe. The angle at which A is cut off at the top is also important. If not just right the vibrations of the caoutchouc tubes are not perfect.

The apparatus above described can be constructed cheaply by any plumber or gas fitter, and is said to work very efficiently.

The Behavior of Metals under Stress.—Interesting and important results have been obtained in the course of the investigations in progress at the Stevens Institute of Technology upon the behavior of metals under stress.

The testing machine invented and designed by Professor Thurston, with its automatic registry, was described in our issue of April last, and its peculiar value in detecting all phenomena of stress, and in affording a reliable and permanent record, is shown by inspection of the curves given in the plate accompanying that article.

The apparatus was exhibited at the last meeting of the National Academy of Science, which was held at the Stevens Institute, and its capability of revealing the action of molecular forces under stress was illustrated. At the close of the session a test piece was left in the machine, strained far beyond its limit of elasticity, to determine, if possible, the existence or non-existence of "viscosity" in the metals.

After twenty-four hours, there appearing no evidence of further yielding, the distorting force was increased, when the discovery was made that the resisting power of the specimen had actually become greater during the period of rest under strain, and the pencil, instead of descending, rose until it indicated an increase of about twenty per cent. in the strength of the sample, and it then traced a path parallel with but above that of the previous day.

Repeated experiments confirmed this remarkable and important deduction of the experimenter:

That metal strained so far as to take a permanent set, and left under the stress producing it, gains in power of resistance up to a limit of time, which in these experiments was about seventy-two hours, and to a limit of increase which has a value, in the best iron, of about 20 per cent., where the applied force is eighty per cent. of the ultimate breaking force.

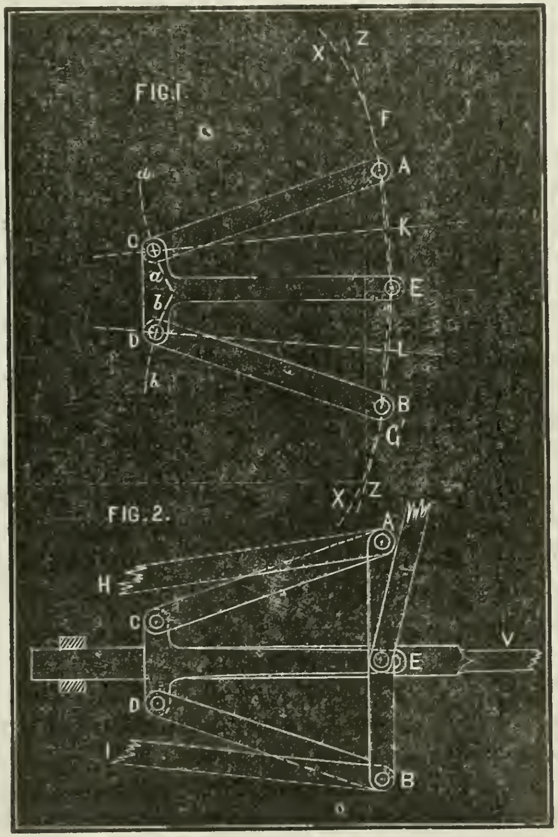
In other words, the metal developes nearly or quite its maximum strength long before reaching the point of rupture, instead of at that point, as when broken at once by a continually increasing stress.

This discovery was announced by Professor Thurston at the annual meeting of the American Society of Civil Engineers, November 5th, and the possible bearing of the earlier experiments of the Committee of the Franklin Institute on "Thermo-Tension," and of the well-known property of the increasing portative force of magnets under strain, as illustrations of related phenomena, were alluded to.

The existence of this property had already been suspected, but it is evident that it could only be conclusively proven by apparatus embodying the principles of that used in this research.

Manufacturers are forwarding for examination samples of metals of all kinds and qualities, and we are able to promise the account of some very interesting results and precise figures and *fac similes* of the diagrams obtained.

A Substitute for Links or Link Motions.—By Hugo Bilgram.—By the arrangement of levers represented in Fig. 1 the end, E, of the T-shaped middle piece is guided in a curve, X X, which,



between F and G, so nearly coincides with the arc of a circle, Z Z, that practically it cannot be distinguished from the latter. The rods A C and B D form the guides of two points of the middle piece, and have their respective fulcrums in A and B, as the engraving shows. For its remarkable property this combination may be utilized to substitute the links of reversible engines that are exposed to destructive influences; for instance, of crane engines in foundries, where the sand suspended in the surrounding air causes a considerable wear of the sliding parts of the engines, and necessitates frequent repairs. It may also be applied on cheap reversible engines, especially if their manufacturers are not provided with suitable facilities to give the link its proper curvature.

In Fig. 2, H and I represent the excentric rods of a Stephenson's link motion, in which the link is substituted in this manner. A plain connecting piece, A B, takes the place of the link, and may be suspended in the usual way. To the ends of the excentric rods are also attached the two guiding rods, A C and B D, to which the T-shaped middle piece is fastened by the pins C and D, the end of which, E, moves directly the valve stem, V, or the rocker. The point E being guided in relation to A B as though it was moving in a slot, conform to Z Z, this arrangement produces the same motion as the ordinary link. By the way of suspension, the corrections of the irregularities between fore and back stroke can be accomplished in this modified link motion as well as in the original one.

A rule for the choice of proper dimensions can be only empirical. A good result may be obtained if the rods A C and B D are made equal to, or at least not much shorter than, the link A B. The dimensions of the T-shaped lever are easily found by first sweeping the circle Z Z of the proper radius, then drawing the chord A B of a length equal to that of the link, and sweeping two arcs, *a a* and *b b*, from A and B, with radii equal to the length of the guiding rods. If, now, the chords A E and B E (E being the vertex of arc Z Z) are perpendicularly divided in two equal parts by the lines C K and D L, then the respective points of intersection, C and D, with the arcs *a a* and *b b*, together with the vertex E, represent the three characteristic joint centers of the middle piece.

The application of this arrangement is not restricted to Stephenson's link motion only, as it may be applied to any other expansion gearing in which a link is used.

A New Process for the Manufacture of Soda.—The well-known, and for nearly a century almost exclusively practiced, process of Leblanc for the manufacture of soda from common salt, has at length, if we may rely upon the opinion expressed by the chemical section of the International Jury at the recent Vienna Exposition, found a formidable rival in a new process, which has been called the Ammonia process.

A similar jury at the Paris Exposition, six years ago, announced the opinion that the process of Leblanc would hold the field for a long time to come ; yet in that brief space of time the new process, then in its infancy, has grown into a flourishing industry, not only successfully competing with the Leblanc, but threatening it, in the immediate future, with comparative extinction.

The process, which presents so revolutionary an aspect, is not new in point of discovery, having been patented in Great Britain over thirty years ago, but from several difficulties, of which the then comparatively moderate demand for soda, the impossibility of obtaining ammonia in large quantity and cheaply, and the inefficient state of that branch of machine building for supplying the necessary plant, were most inseparable, the new invention was abandoned. Subsequent to this early attempt, the ammonia process was several times resuscitated in various European countries, but as often abandoned. Now, however, that the difficulties in its development are removed, it has lately started into life, and developed to an extent surprising even to those fully aware of the possibilities inherent in it.

The new process is based upon the reaction of the bi-carbonate of ammonia with a strong solution of common salt. The result of this interaction is the precipitation of most of the sodium as bi-carbonate, while the resulting chloride of ammonium remains in solution. From this chloride the ammonia is expelled, with the aid of quick-lime, to be employed in a second operation. The bi-carbonate of soda, as produced, is converted to the simple carbonate (the soda of commerce) by simply heating, and the equivalent of carbonic acid so driven off is led into the ammonia to convert it again into the bi-carbonate. thus making the process a continuous one.

These are the general features of the new soda process, which has suddenly grown into such importance. Many minor details are as yet unknown, though enough is known to make it evident that it possesses several striking advantages over that of Leblanc. The most obvious of these resides in the fact that, with the new process, the conversion of the salt into soda is direct, while with the Leblanc, as is well known, the conversion is effected indirectly by several intermediate steps. Again, none of the heavy metals are precipitated from the brine, and the product is said to be absolutely free from sulphur compounds—a source of great annoyance with the old method. Lastly, but not least, the plant is simple and comparatively inexpensive, and no noxious gases or waste products are produced. The chloride of calcium, the only waste product which the new process entails, is inoffensive, and, from indications, the demand for it in several new and growing industries will absorb much of what may be supplied from this source.

It is stated upon reliable authority that there are large soda works in England, Hungary, Switzerland, Westphalia, Thuringia, Baden and elsewhere, operating the new ammonia process, the daily production of some of which amounts to as much as fifteen tons.

It is yet too soon to speculate upon the influence which the growth of the new manufacture will exert upon many branches of chemical and related industries ; but from the leading position occupied by soda in these departments and the inter-dependence in production and consumption of this and many other chemical substances largely employed in the arts, such as sulphuric acid, hydrochloric acid, chloride of lime, etc., indirectly affectingthese arts themselves, this influence must be both wide-spread and important.

Peruvian Nitrate of Soda.—It is said that the Nitrate of Soda trade has wonderfully increased within the last twenty-five years. In 1848, three vessels were sufficient to supply the demand, while now one hundred vessels are waiting for cargoes at the port of Iquique. A railway now connects the port with the saltpetre districts of the interior, and through its entire length is surrounded by manufactories.

Thirty-one establishments, supplied with excellent machinery, are now in operation, and capable of producing 1250 tons per diem. Twenty-one additional establishments are being constructed, so that, in a short time, it is estimated, the production will amount to 19,000 tons a day, or to no less than 5,750,000 tons a year.

Civil and Mechanical Engineering.

THE PRINCIPLES OF SHOP MANIPULATION FOR ENGINEERING APPRENTICES.

By J. Richards, Mechanical Engineer.

[Entered according to the act of Congress, in the year 1873, by John Richards, in the office of the Librarian of Congress at Washington.]

(Continued from page 327.)

The Objects of Mechanical Industry.

Mechanical engineering, like every other pursuit, is directed to the accumulation of wealth; and, as the attainment of any purpose is more surely achieved by keeping that purpose continually in view, there will be no harm, and perhaps no little gain, derived by an apprentice considering at the beginning the main object to which his efforts will be directed after learning his profession or trade.

So far as an abstract principle of motives, it is of course useless to consider this subject in connection with engineering operations or shop manipulation; but the subject of commercial gain has a practical application, to be followed throughout the whole system of industrial pursuits, and is as proper to be considered in connection with machine manufacturing as mechanical principles or the functions and objects of machines.

"Cost" is the element that continually modifies or improves manufacturing processes, determines the success of every establishment, is continually present in making drawings, patterns, forgings and castings.

Machines are constructed because of the difference between what they cost and what they sell for—between the manufacturing cost and their market value when they are completed.

It seems hard to deprive engineering pursuits of the romance that is often attached to the business, and bring it down to a matter of commercial gain, but it is best to deal with facts, especially when such facts have an immediate bearing upon the object in view.

There is no intention in these remarks of disparaging the works of many noble men, who have given their means, their time, and sometimes their lives, to the advancement of scientific truths, without hope or desire of any other reward than the satisfaction of having performed a duty.

The following propositions will place this subject of aims and objects before the reader in the sense here intended:

First. The object of engineering pursuits is commercial gain, the profits derived from the planning and construction of machinery.

Second. The gain so derived is as the difference between the cost of constructing machinery, and the market value of the machinery produced.

Third. The difference between what it costs to plan and construct a machine and what it will sell for, is generally as the engineering knowledge and skill that is brought to bear in producing the machine.

This last sentence brings the matter into a tangible form, and indicates what the subject of gain should have to do with what an apprentice is to learn of machine construction.

Success in an engineering enterprise may be temporarily achieved by illegitimate means, such as misrepresentation as to the capacity and quality of what is produced, the use of cheap or improper material, or by copying the plans of others to avoid the expense of engineering service, or from want of engineering ability; but, in the end, the permanent success of such a business must rest upon the knowledge and skill that is connected with it.

By examining into the facts, the apprentice will find that all truly successful establishments have been founded and built upon the mechanical abilities of some person or persons that formed a base upon which the business was reared, and that this is the essential element that must in the end lead to permanent success.

The material and the labor which make up the first cost of machines is, taking an average of various classes, nearly equally divided; labor being in excess for the finer class of machinery, and the material in excess for the coarser kinds of work.

The material is presumed to be purchased at the same rates by those that are well skilled as by those of inferior skill, so that the difference in first or manufacturing cost is determined by skill exclusively.

This skill consists in preparing plans and in various processes for connecting and shaping the material, which will be noticed in their regular order.

The amount of labor and consequently the cost of machinery produced is as the number of these processes and the time consumed in each.

The business of the mechanical engineer is to reduce the number of these processes or operations, and to shorten the time in which they may be performed.

A careful study of shop processes or operations, including designing, draughting, moulding, forging and fitting, is the secret of success in engineering practice, or in the management of manufactures.

The advantages of an economical design, or the most carefully prepared drawings, are easily neutralized and lost by careless or improper manipulation in the workshop; an incompetent manager may waste more pounds in shop processes, than the commercial department can save pence in buying and selling.

This importance of shop processes in machine construction is realized by proprietors, but not generally understood in all of its bearings; yet the apprentice may notice the continual effort that is made to augment production in engineering works, which is the same thing as shortening the processes.

By reasoning in this manner the apprentice will form true standards by which to judge of plans and processes that he is brought in contact with.

A machine may be mechanically perfect, arranged with symmetry, true proportions and correct movements; but if such a machine has not commercial value, and is not applicable to a useful purpose, it is as much a failure as though it were mechanically inoperative. In fact, this consideration of cost and commercial value must be continually present, and a mechanical education that has not furnished true conceptions of the relations between commercial cost and mechanical excellence, will fall short of achieving the objects for which such an education is undertaken.

ON THE NATURE OF MACHINERY.

Machines may be defined in general as agents for transmitting and applying power, or motion and force, which constitutes power.

By machinery the natural forces are utilized, and directed to the performance of operations where human strength is insufficient, or when natural force is cheaper, and when the rate of movement exceeds what the hands can perform.

The term "agent" applied to machines conveys a true idea of their nature and functions. Machines do not create power or consume power, but only transmit or apply it; and it is only by conceiving of power as a constant element, independent of all kinds of machinery, that the learner can have a true conception of the nature of machines. When once there is in the mind a fixed conception of power, dissociated from every kind of mechanism, there is laid a solid foundation on which a knowledge of machines and mechanics may be built up, but without this conception correctly fixed in the mind, it is not only impossible to appreciate the true nature of machines, but difficult to understand even the most simple principles in mechanism.

To believe a fact is not to learn it, in the sense that this term may be applied to mechanical knowledge; to believe a proposition is not to have a conviction of its truth, and what is meant by learning mechanical truths is to have them so firmly fixed in the mind that they will involuntarily arise to qualify everything met with that involves mechanical movement.

An apprentice or student that in his yonnger days has had the misfortune to confound power with machinery for transmitting it, as taught in school-books on mechanical philosophy, will find these impressions remain in his mind for years, even after he has become acquainted with the true principles of mechanism. For this reason the apprentice is urged to start rightly, first acquiring a clear and fixed conception of power, and next of the nature and classification of machines, for without the first he cannot have the second.

I am well aware of the difficulty that must be encountered in attempting to learn the nature and classification of machines without the aid that may be derived from a knowledge of their practical application; but to learn such practical application first is certainly to commence wrong, because of the waste of time and effort that is required by such a course; and, while it may be difficult to form such clear conceptions of machines by studying their nature and general principles in advance of being acquainted with their application, it is by no means impossible to do so.

Machinery is divided into four classes, each constituting a division, that is clearly defined by the functions it performs, as follows:

First. Motive machinery for utilizing natural forces.

Second. Machinery for transmitting and distributing power.

Third. Machinery for applying power.

Fourth. Machinery for transportation.

Or, more briefly stated: Motive machinery, machinery of transmission, machinery of application and machinery of transportation.

I will now proceed to consider these divisions of machinery with a view to making the classification more clear, and shall revert briefly to the principles of operation in each division; and as this dissertation will form a kind of base upon which the practical part of the treatise will in a measure rest, it is trusted that the reader will not only carefully consider each proposition that is laid down, but will add others from his own deductions as he goes along.

MOTIVE MACHINERY.

In this class belongs steam engines, caloric or air engines, water wheels or water engines, and wind wheels or pneumatic engines. These four types comprehend the motive power, as it is termed, of the present day.

In considering these engines for motive power in a way to best comprehend their nature, the first view to be taken is that they are all directed to the same end, and all deal with the same power, and, if possible, to avoid the impression of their being different kinds of power, as the terms usually employed seem to imply. We speak of steam power, water power or wind power; but power is the same from whatever source derived, and these distinctions merely indicate different natural sources from which power is derived.

Primarily, power is the product of heat, and wherever force and motion exist, they can be traced to heat as the generating element, whether the medium through which the power is obtained be by the expansion of water or gases, the gravity of water or the force of wind, heat will always be found as the prime source.

As steam engines constitute a great share of machinery that is commonly met with, and as a class of machinery naturally engrosses attention in proportion to its importance, the study of mechanics generally begins with steam machinery. The subject of steam power, aside from its mechanical consideration, is one that may afford many useful lessons, by tracing its history and its influence, not only upon mechanical industry, but upon human interests generally. The subject is often hinted at, and its importance conceded, but no one has from statistical and other sources ventured to estimate in a methodical way the changes that can be traced directly and indirectly to steam power.

The steam engine is the most important and in America and England best known among motive agents. The importance of steam contrasted with other sources of motive power is not due to the cheapness of cost at which power is in this way obtained, but for the reasons that amount of power produced can be governed at will, the power can be produced without reference to local conditions, and in any place; the machinery can with its fuel and water, the elements of its power, be transported from place to place, as in the case of machinery for transporting, the locomotive not only supplying power for its own transit, but carrying besides vast loads of merchandise or travel. For manufacturing processes the main advantage of steam power rests in the fact that power can be taken to the material, and beside other advantages gained thereby, is the difference in weight and cost between transporting the manufactured product and the raw material. In the case of iron manufacture, for example, it would cost ten times as much to transport the ore and the fuel used in smelting as it does to transport the manufactured iron; steam power saves this difference, and without steam power our present iron traffic would be impossible.

The steam engine, in the sense in which the term is employed, means not only steam using machinery, but steam generating machinery or plant; it includes the engine proper, with the boiler, mechanism for feeding water to the boiler, also for governing speed, with indicators and other details.

The apprentice must guard against the too common impression that the engine, cylinder, piston, valves, and so on, are the main parts of steam machinery, and that the boiler and furnace are only auxiliaries. The boiler is the soul of the whole, the part where the power is generated, the engine being merely an agent for transmitting power from the boiler to the work that is to be performed. This conclusion would, of course, be reached by any one in reasoning about the matter and following it to a conclusion, but the fact should be fixed in the mind as a principle of steam power.

When we look at a steam engine there are certain impressions conveyed to the mind, and by these impressions we are governed in a train of reflection that follows. We can conceive of the cylinder and its details as a complete machine with independent functions, or we can conceive of it as a mechanical device for transmitting force from the boiler, and this conception may be independent of, or even contrary to, specific knowledge that we at the same time possess; hence the importance of starting with a correct idea of the boiler being, as we may say, the base of steam machinery.

As reading books of fiction sometimes expands the mind and enables it to grasp great practical truths, so may a study of theoretical principles enable us to comprehend the simplest forms of mechanism. Even Humboldt and Agassiz resorted to imaginative speculations as a means of expanding their minds.

In no other branch of machinery has so much research and experiment been made during eighty years past as in steam machinery, and, strange to say, the greater part of this research has been directed to the details of engines, and yet there has been no improvement made during the time that has effected any considerable saving of heat or expense. The steam engines of fifty years ago, considered as steam using machines, utilized nearly the same proportion of the energy or power developed by the boiler as the most improved engines of modern construction—a fact that in itself indicates that the engine is not the vital part of steam machinery. There is not the least doubt that if the efforts to improve the steam engine had been mainly directed to economizing heat and increasing the evaporative power of boilers, much more would have been accomplished.

This remark, however, does not apply to the present day, when the principles of steam power are well understood, and when heat is recognized as the proper element to deal with in attempts to economize in the cost of power.

There is, of course, various degrees of economy in steam using as well as in steam generating machinery, but so long as the best steam machinery does not utilize but one-tenth or one-twelfth of the heat that is represented in the fuel burned, there need be no question as to the point where improvements in such machinery should begin.

With these remarks as to steam power in general, I will proceed to consider the principles upon which steam engines operate.

A cubic inch of water, by taking up a given amount of heat, is expanded to more than five hundred cubic inches of steam at a pressure of forty-five pounds to the square inch.

This extraordinary expansion, if performed in a close vessel, would exert a power five hundred times as great as would be required to force the same quantity of water into the vessel against this expansive pressure; in other words, the volume of the water when put into the vessel would be but one five-hundredth part of its volume when it is allowed to escape, and this expansion, when confined in a steam boiler, exerts the force that we term steam power.

This force or power is through the means of the engine communicated and applied to different kinds of work where force and movement are required. The water, like the engine and the boiler, is merely an agent through which the energy or power of heat is applied.

This brings us to the original proposition that power is heat, and heat is power, the two being convertible and, according to modern science, indestructible; so that the power, when used, must give off its mechanical equivalent of heat, or heat, when applied, develop its equivalent in power. If the whole amount of heat represented in the fuel used for a steam engine could be utilized, the effect would be, as before stated, from ten to fifteen times as great as it is in actual practice, from which it must be inferred that a steam engine is a very imperfect machine for utilizing heat.

This loss arises from the fact that the heat cannot be directly nor fully communicated to the water.

To store up and retain the water after it is expanded into steam, a strong vessel, which we term a boiler, is required, and all the heat that is imparted to the water has to pass through the plates of this boiler, which stand as a wall between the heat and its work.

Reasons for the extended and general use of steam as a power, besides those already named, are to be found in the fact that n other available element or substance can be expanded to a given degree, at so small a cost as water; and in the fact that its temperature will not rise to a point that will destroy the machinery for generating and using steam, and, further, in the very important property of lubrication that steam has in protecting the frictional surfaces of pistons and valves, which it is impossible to keep oiled because of their inaccessibility and the high temperature.

To summarize, we have the following propositions relating to steam machinery.

The steam engine is an agent for utilizing the power of heat and applying it to useful purposes.

The power of the heat is obtained by expanding water in a confining vessel, and employing the force exerted by the pressure thus obtained.

The power obtained is as the difference of volume between the feed water when forced into the boiler, and the volume of the steam that is drawn from the boiler, or as the amount of heat taken up by the water.

The heat that may be utilized is what will pass through plates of the boiler, and but a small share of what the fuel produces.

The boiler is the main part, where the power is generated, and the engine is but an agent for transmitting this power to the work to be performed.

An engine, when well constructed, transmits the power generated by the boiler with but little loss, but the best constructed boiler, as said, can only utilize but a small portion of the heat represented in the fuel.

The loss of power due to its transmission through an engine is from radiation of heat, the escape of steam at pressure after acting on the piston, and the friction of moving parts.

By condensing the steam before it leaves the engine, so that it is returned to the air as water, and of the same volume as when it entered the boiler, there is a saving equal to the pressure of the atmosphere.

These propositions relating to steam engines, if remembered and studied by apprentices in connection with steam machinery, will lead to a reasoning about the principles, as well as of the mechanism, and render the nature of steam power more easily understood.

Engines operating by means of hot air, called caloric engines, and engines operated by gas, or explosive substances, all act substantially upon the same general principles as the steam engine; the greatest distinction being between the generation of heat by the combustion of fuel and by chemical action.

With the exception of caloric or air engines, however, there is but a limited use of any but steam engines for motive power, and it may be safely assumed that the learner who has mastered the general principles of the steam engine will find no trouble in analyzing and understanding any similar machinery acting from expansion due to heat, whether air, gas or explosive agents be employed. This method of treating the subject of motive engines will no doubt be presenting it in a new way, but it is merely beginning at an unusual place, nothing more. And the learner who commences with first principles, instead of pistons, valves, connections, and bearings, will find in the end that he has not only adopted the true plan, but the shortest one to understanding steam and other expansive engines.

WATER POWER.

Water-wheels, next to steam engines, are the most common motive agents. For centuries water-wheels remained without much improvement or change, down to the period of Turbine water-wheels, when it was discovered that instead of being a very simple matter, the application of water power was found to involve some very intricate conditions, and gave rise to many problems of scientific interest, that in the end produced the modern Turbine wheels.

A modern Turbine water-wheel, of the best construction, operating under favorable conditions, gives a per centage of the power of the water that almost reaches the theoretical coefficient of its gravity, and it may be assumed that there will in the future be but little improvement made in such water-wheels except in the way of simplifying and cheapening their construction. In fact, there is no other class of machines that seems to have reached the same state of improvement as water-wheels, nor any other class of machinery that is constructed with the same uniformity of design and arrangement in different countries and by different makers.

Every one remembers the classification of water-wheels met with in the older school-books on natural philosophy, where we are informed that there are three kinds of wheels, as there were "three kinds of levers," namely, overshot, undershot, and breast wheels, with a brief notice of Barker's mill, than ran apparently without any good reason for so doing.

Without finding fault with this plan of describing water-power, farther than to say that a little explanation of the principles by which power is derived from the water would have been more useful, I will venture upon a different classification of water-wheels, that is more in accord with modern practice, and without reference to the special mechanism of the different wheels, except when unavoidable.

Water-wheels can be divided into four general types:

First. Gravity wheels, acting directly from the weight of the water which is loaded upon one side of a wheel revolving in a vertical plane, the weight resting upon the wheel until the water has reached the lowest point where it is discharged.

Second. Impact wheels, driven by the force of spouting water that expends its percussive force against the floats tangentally to the course of rotation and at a right angle to the face of the floats or vanes.

Third. Reaction wheels, that are "enclosed," as it is termed, and filled with water under pressure, that is allowed to escape through tangental orifices, the force being derived from the unbalanced pressure within the wheel or from the reaction due to the weight of the water that is thrown off from the periphery.

Fourth. Pressure wheels, acting in every respect upon the principle of a rotary steam-engine, except in the differences that arise from operating with an elastic and a non-elastic fluid, the pressure of the water resting continually against the floats or abutment, without chance to escape except by the rotation of the wheel.

To this classification might be added combination wheels, acting partly by the gravity and partly by the percussion force of the water; or acting partly by impact and partly by reaction, or by impact and pressure, which are common conditions of operation in water-wheels.

The water-wheel or water-power, as a mechanical subject, is apparently quite disconnected with shop manipulation, but serves as a good example for conveying general ideas of force and motion, and, on these grounds, will warrant a more extended notice than the seeming connection with the general subject would otherwise call for.

In the remarks upon steam-engines it was explained that power is derived from heat, and that the water and the engine were both to be regarded as agents through which power was applied, and, further, that all power is a product of heat.

There is, perhaps, no problem in the whole range of mechanics more interesting than to trace the application of this principle to water-wheels: one that is not only interesting but instructive, and may suggest to the mind of the apprentice a course of investigation that will apply to many other matters connected with power and mechanics.

The power derived from water by means of wheels is due to the gravity of the water in descending from a higher to a lower level; but the question arises, What has heat to do with this? if heat is the source of power, and power a product of heat, there must be a connection somewhere between heat and the descent of the water.

Water in descending from one level to another can give out no more power than was consumed in raising it to the higher level, and this power we will find to be heat.

Water is evaporated by heat of the sun, expanded until it is lighter than the atmosphere, rises through the air, and by condensation falls in the form of rain over the earth's surface, then drains into the ocean through streams and rivers, to again resume its round by evaporation, giving out power in its descent that we turn to useful account by means of water-wheels.

Evaporation is continually going on; the rainfall is likewise quite constant, so that streams are maintained within a sufficient regularity to be available for operating machinery.

The analogy between steam-power and water-power is, therefore, quite complete. Water is, in both cases, the medium through which power is obtained; evaporation is also the leading principle in both cases, the main difference being that in the case of steam-power there is used a force arising directly from the expansion of water by heat, and in water-power a force which is an indirect result of expansion by heat.

Returning to the classification of water-wheels, gravity, or "overshot" wheels, as they are called, seem to be the most effective and capable of utilizing the whole effect due to the gravity of the water; but in practice this is not the case, and it is only under peculiar conditions that wheels of this class are preferable to turbine wheels, and in no case will they give out a greater per cent. of power than turbine wheels of the best class. The reasons for this will be apparent by examining the conditions of their operation.

A gravity wheel must have a diameter equal to the fall of water, or, to use the technical name, the height of the head. The speed at the periphery cannot well exceed sixteen feet per second without losing the effect due to the descending gravity of the water. This produces a very slow axial speed, and a train of multiplying gearing becomes necessary in order to reach the speed required in most operations where power is applied. This train of gearing, besides being liable to wear and accident, and costing usually a large amount as an investment, consumes a considerable share of the power by frictional resistance, especially when the gearing consists of tooth wheels.

Gravity wheels, from their large size and their necessarily exposed situation, are subject to be frozen up in cold climates; and, as the parts are liable to be first wet and then dry, or warm and cold by exposure to the air and the water alternately, the tendency to corrosion of iron, or decay if of wood, is much greater than in submerged wheels.

Gravity wheels, to realize the fullest effect from the water, require a diameter so great that they must drag in the water at the lower or delivering side, and are especially affected by back water, to which all wheels are more or less liable, from the reflux of tides or by freshets.

These are among the most notable of the disadvantages pertaining to gravity wheels, which have, with other reasons, such as the inconvenience of manufacturing them, first cost, and so on, driven such wheels out of use by the force of circumstances rather than by actual tests or theoretical deductions.

Impact wheels, or those driven by the percussive force of water, including the class termed turbines, are now generally used for heads of all heights.

The theory of their action may be explained in the following propositions:

The spouting force of water is theoretically equal to its gravity.

The percussive force of water can be utilized to its full extent if its motion is altogether arrested by the floats of the wheel.

The force of the water is greatest by its striking against planes at right angles to its course.

Any force represented by the water rebounding from the floats parallel to their face, or at any angle reverse to the motion of the wheel, is lost.

This rebounding action becomes less as the columns of water projected upon the wheel are increased in number and diminished in size.

To meet the conditions of rotation in the wheel, and to facilitate the escape of the water without dragging, after it has expended its force upon the vanes, the reversed curves of the turbine arrangement become necessary.

Keeping these general principles in view, the apprentice will be able to understand in general the construction of impact wheels.

The modern turbine has been the subject of the most careful investigation, by able engineers, and there is no lack of mathematical data to be referred to and studied after the general principles are understood. It is a subject of great complicity, if followed to detail, and, perhaps, less useful to a mechanical engineer, who does not intend to confine his practice to water-wheels, than other subjects that may be studied with more advantage. The subject of water-wheels may be called an exhausted one, that can promise but little return for labor spent upon it with a view to improvements; the efforts of the ablest hydraulic engineers have not added much to the percentage of useful effect realized by turbine wheels during fifteen years past, and their present performance is quite equal to anything that can be hoped for in future.

This matter is alluded to for the reason that in choosing any particular branch for a specieal study, an apprentice should select such as are least perfect, and present the best chance for improvement, instead of such things as there is every reason to believe have reached a reasonable state of perfection, and are in the future to remain substantially the same.

The last statement of course applies only to a few branches in the engineering arts, and perhaps more fully to water-wheels than to any other.

Reaction wheels are used only to a limited extent, and will soon, no doubt, become extinct as a class of water-wheels.

In speaking of them, I will select what is known as Barker's mill for an example, because of the familiarity with which it is known, although its construction is greatly at variance with modern reaction wheels.

A query as to the principle of action in a Barker wheel, while it may be very clear in a scientific sense, still remains a puzzle to the minds of many who are well versed in mechanics, some contending that the power is directly from pressure, others that it is from the dynamical effect due to reaction. It is one of the problems so difficult to determine by ordinary standards, that it serves for endless debate between those who hold to different views; and, considering the advantage that is derived from such controversies, perhaps the most useful manner of disposing of the problem here is to state the two sides as clearly as possible, and leave the reader to determine for himself which he thinks right and which wrong.

Presuming the vertical shaft and the horizontal arms of a Barker wheel to be filled with water under a head of sixteen feet, there would be a pressure of about seven pounds upon each inch of surface within the cross arm, exerting an equal force in every direction. By opening an orifice at the sides of these arms equal to one inch of area, the pressure would at that point be relieved by the escape of the water, and the internal pressure be unbalanced to that extent. In other words, opposite this orifice, and on the other side of the arm, there would be a force of seven pounds that was not balanced, and would act as a propelling force in turning the wheel.

This is one theory of the principle upon which the Barker wheel acts, that has been laid down in Vogdes' Mensuration, and perhaps elsewhere, as an explanation.

The opposing theory is that, direct action and reaction being equal, ponderable matter discharged tangentally from the periphery of a wheel must create a reactive force equal to the direct force with which the weight is thrown off. To state it more plainly, the spouting water that issues from the arm of a Barker wheel must react in the opposite course in proportion to its weight.

The two propositions may be consistent with each other and even identical, but there still remains an apparent difference.

The latter seems a plausible theory, and perhaps a correct one; but there are two facts in connection with the operation of reaction water-wheels that seem to controvert the latter and favor the first theory, namely, that reaction wheels seldom utilize more than forty per cent. of useful effect from the water, and that their speed may *exceed the initial velocity of the water.* With this the subject is left as one for argument and investigation on the part of those who choose to consider it.

Pressure wheels, like gravity wheels, would, upon theoretical inference, be expected to give a high per cent. of power, the water resting with the whole of its weight against the vanes or abutments, and without chance of escape except by turning the wheel, would seem to meet the true conditions of realizing the whole force; and so it would, if such wheels had not to contend with certain mechanical difficulties that render them impractical in most cases.

A pressure wheel, like a steam-engine, must include running contact between water-tight surfaces, and, like a rotary steam-engine, running contact between water-tight joints that move at degrees of speed that varies in the same joint, and when it is considered that the most careful workmanship has never produced rotary engines that would surmount these difficulties in working steam, it can hardly be expected they may be overcome in using water, that is liable to be filled with grit and sediment, and lacks the peculiar lubricating property of steam.

A rotary steam-engine is in effect the same as a pressure water-wheel, and the apprentice in studying the first will fully understand the principles of both by supposing steam to be substituted by water.

WIND POWER.

Wind power, aside from the objection of uncertainty and irregularity, is the cheapest source of power. Steam machinery, besides costing a large sum as an investment, is continually deteriorating in value, consumes fuel and requires skilled attention. Water-power also requires a large investment, greater in many cases than steam-power, and in most places the plant is in danger of destruction by freshets; but wind-power is cheap in every sense, except that it is unreliable for constancy except in special localities, and these, as it happens, are for the most part distant from other elements of manufacturing industry.

The operation of wind-wheels is so simple and so generally understood, that no reference to mechanism need be made here.

The force of the wind, moving in right lines, is easily applied to producing rotary motion, the difference from water-power being mainly in the weakness of the wind currents and the greater area of the surfaces required to act upon. Turbine wind-wheels have been constructed very much the same as turbine water-wheels.

In speaking of wind-power, the propositions about heat must not be forgotten; in fact the apprentice should so school his mind and habits of thinking that, whenever the subject of power is to be considered in any way, he will at once trace out the connection with heat.

We have seen how heat is almost directly utilized by the steam-engine, and how the effects of heat are utilized by water-wheels, and the same connection will be found with wind-wheels or wind-power; because currents of air are due to changes of temperature, and the connection between the heat that produces such air currents and their application as power is no more intricate than in the case of water-power.

MACHINERY FOR TRANSMITTING AND DISTRIBUTING POWER.

To construe the term, transmission of power, in a critical sense, it should, when applied to machinery, include nearly all that has motion; for, with the exception of the last movers, or where the power passes off and is expended upon the work to be performed, all machinery, of whatever kind, can be regarded as machinery of transmission. Custom has, however, confined the use of the term to such devices as are employed to convey power from one place to another, without including the organized machinery through which power is applied immediately to the performance of work.

Power is transmitted by means of shafts, belts, friction-wheels, gearing, and in some cases by water or air, as the conditions of the work may require. Sometimes such machinery is employed as the conditions do not require, because there is, perhaps, nothing of equal importance connected with mechanical engineering about which there exists so great a diversity of opinion or in which there is a greater diversity of practice than in devices for transmitting motion.

I do not refer to questions of mechanical construction, although the remark is equally true if applied in this sense, but to the kind of devices that are best in special cases.

It is not proposed, in this part at least, to treat of the construction of machinery for transmitting power, but to search after the conditions that should determine which of the several plans, whether belts, gearing or shafts, should be employed, and the principles upon which they operate.

Practical examples do not often furnish data as to the advantages of the different plans for transmitting power, because a given duty may be successfully performed by belts, gearing, or shafts, even by water, air or steam, and the comparative advantages of different systems is not always an easy matter to determine. Machinery of transmission being generally a part of the fixed plant, experiments cannot be made to institute comparisons, as in the case of machines; besides there are special or local considerations, such as noise, danger, freezing and distance to be taken into account, which prevent any rules of general application. Yet in every case it may be assumed that some particular plan is better than any other, and that plan can best be determined by studying first the principles of the mechanism, next the special conditions that exist, and thirdly precedents or examples.

A leading principle in machinery of transmission that more than any other furnishes data for strength and proportions is, that the stress upon the machinery, whatever it may be, is inversely as the speed at which it moves. For example, a belt two inches wide, moving one thousand feet a minute, will theoretically perform the same work that one ten inches wide will do, moving at a speed of one hundred feet a minute; or a shaft making two hundred revolutions a minute will transmit four times as much power as a shaft making but fifty revolutions in the same time, the torsional strain being the same in both cases.

This proposition argues the expediency of reducing the proportions of mill gearing and increasing its speed; but there exists other conditions that makes a limit in this direction, such as the speed at which bearing surfaces may run, centrifugal strain, jar, and vibration. The object is to fix upon a point between what high speed, light weight, cheapness of cost would suggest, and what the conditions of practical use and endurance demand.

(To be continued.)

REPORTS OF THE COMMITTEE ON THE MODE OF DETERMINING THE HORSE-POWER OF STEAM BOILERS.

At a Meeting of the Franklin Institute, held Nov. 19, 1873, it was resolved that the accompanying statement precede the reports, viz:

At the stated meeting of the Institute, held October 15th, 1873, the accompanying reports from the "Committee on the Mode of Determining the Horse-Power of Steam Boilers," were presented.

It was thereupon resolved that, while not formally adopting the views of either report, the Institute accept the same; and, further, that both reports be published in the Journal for the information of the members. The Chairman then gave a brief history of the work of the Committee, and concluded by urging its discharge.

It was, thereupon, on motion, resolved "that the Committee be discharged, and that the thanks of the Institute be presented to the gentlemen composing it for the faithful manner in which they had performed their laborious task."

It may be remembered that this Committee was constituted over three years ago with five members, and brought in a report on June 21st, 1871, and an additional report June 18th, 1872, both of which were published in the Journal.

At the meeting in October, 1872, the two reports were discussed, and the Institute referred the subject again to the Committee for more explicit directions, which would make the same available to practical engineers. A difference of opinion also existing as to the amount of evaporation which should be considered as horse-power, the Committee was enlarged by three additional members, representing the manufacture of modern sectional boilers, making the number of the Committee eight. The following reports, numbered 3 and 4, exhibit fully the two views taken of the question: Ed.

Report No. 3.

So far as the investigations of the committee have extended, they find no reason for changing the statement in relation to the practice of English boiler manufacturers of providing an evaporative capacity equal to one cubic foot of water at the boiling point turned into steam hourly under atmospheric pressure for each nominal horse power; this practice has grown up where forty pounds per square inch is regarded as high pressure.

The practice of American engineers makes a different demand on the boiler; higher pressures are required, and the boiler manufacturer has to furnish heat absorbing surface of greater strength; in fact, the chief requirements of the boiler to be used for a manufactory are strength and surface. These cost the maker money, and they are sought by the purchasers of boilers at the lowest price they can procure them. Under these conditions the practice of engine and boiler makers has for some years been growing away from the English precedents; the economy of higher steam pressure has been already sufficiently demonstrated to here require no further discussion, and the conclusions naturally resulting from these changes in practice seem irresistible; we therefore submit the facts.

It has been frequently suggested that the designation of the size or capacity of boilers by the term horse-powers, although it has been used for about fifty years, is inapt and uncertain—the term horse-power being a dynamic expression, and the dynamic effect of a given quantity of steam varying with the engine in which it is used.

To describe the size of a boiler in its evaporative capacity per hour, under stipulated conditions, is preferable.

The conditions vary with different boilers, and should entirely be in the control of the party assuming the responsibility of the performance of the boiler. They embrace temperature of feed, pressure of steam, quantity and form of fuel, arrangement of grate proportions, forms of furnace and flue, volume and force of draft, condition of heat-absorbing surface, and, in short, every thing that affects either the combustion of fuel or the absorption of heat by the boiler.

The making of any uniform empirical standard of evaporation, equivalent to a horse-power, applicable to all boilers that can be verified by experiment is impracticable, because changes in working pressure are attended with changes in the dynamic effect or power with the same evaporative capacity, and such changes are not in direct ratio either with the increased pressure or with the degree of expansion practised in the engine.

In presenting this matter to the notice of the Institute, it would seem proper to call attention to the phenomena resulting from varying steam pressure and variations in expansion.

To do this a series of diagrams have been prepared, copied and modified* from Professor Trowbridge's book on the subject—the result of extended experiments, made in the Novelty Iron Works, N. Y., and checked by careful comparison with other published experiments.

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* The modification consists in making the atmospheric pressure the zero initial point in starting pressure, so as to correspond with the steam gauges now generally used, instead of an absolute vacuum 14·7 lbs. below the atmosphere.

(No. 1.) The first diagram shows the number of pounds of water required to produce one indicated horse-power, in a non-condensing engine, at different pressures and different points of cut-off.

(No. 2). The second shows the theoretical quantity and the actual quantity of water required per horse-power per hour, with steam at 80 pounds per square inch pressure, cut-off at various points in the stroke. These experiments were made on engines of the slide-valve type, the valves at each end of the cylinder and clearances equal to five per cent. of the piston displacement.

The upper curve is obtained from an engine of more than ten cubic feet cylinder capacity, and the next lower curve from one of less than one cubic foot cylinder capacity.

The lowest line is from a computation of specific volume, according to Mariotte's Law," without clearances, and the line above it, from a similar calculation, embracing clearances equal to one-twentieth of the piston displacement.

(No. 3.) The third diagram shows the increase of horse-power due to increased pressure with the same rate of evaporation.

(No. 4.) The fourth diagram shows the quantity of water required to be evaporated in a boiler to produce one horse-power with different steam pressures in a theoretically perfect non-condensing steam engine.

An examination of these diagrams will serve to show the impracticability of establishing any uniform system of rating steam boilers in horse-powers by any easy mode of computation.

It is the experience of all engineers that moderate excess of steam boiler capacity, beyond the actual requirements of the engine, is attended with economy in fuel, and a stint of boiler with waste of fuel.

In view of variations of capacity of the same boiler under varied conditions, the discontinuance of the term horse-power, as descriptive of the size and capacity of the boiler, would appear to be proper; and it is suggested as preferable that purchasers and makers should, instead, describe fully and in accurate terms the evaporative capacity of boilers proposed, and the conditions under which they are to be worked and tested, or to specify the indicated horse-power to be developed in an engine under fully and exactly stipulated conditions of speed, pressure, economy and grade of expansion.

In conclusion, the following mode of making tests of the evaporative capacity of steam boilers is suggested as being easily managed by persons practically familiar with steam machinery, and only involving apparatus which can be readily procured in most manufacturing establishments.

That the water be weighed in, and pumped from, a tank placed on a platform scale, the temperature at which it enters the boiler measured by a thermometer inserted in the feed pipe, the pressure at which the steam is delivered is determined by a steam gauge, and its temperature by a thermometer inserted in the steam pipe near the boiler.

In case of boilers exceeding 100 cubic feet hourly evaporative capacity, measuring of the water in a tank is preferable as being more convenient.

A convenient means of applying thermometers in water and steam pipes is to screw a hollow plug of iron, open at the top and closed at the bottom, vertically into the upper side of the pipe, so that the lower portion of the plug is in the current flowing through the pipe. Into the cavity of the plug a little quicksilver is dropped, and the bulb of the thermometer is inserted in it. The function of the quicksilver is to secure prompt conduction of heat from the tube to the thermometer bulb.

The preferable form of thermometer for this use is that known in the trade as chemical thermometers; the whole instrument, including its porcelain scale, being enclosed in a glass tube.

The advantage of this mode of applying thermometers is that the thermometer is not exposed to pressure, as it is when directly inserted in the pipe, and, in the event of breaking, no leak from the pipe ensues, and the plugs, which are inexpensive, remaining in the pipe, the thermometer can be readily applied or removed without interruption to the working of the boiler.

The weight of a cubic foot of water at 212° is almost exactly 60 pounds avoirdupois.

When the water is measured at temperatures say between 45° and 70° Fahrenheit, $4\frac{1}{4}$ per centum should be added for the increase in volume, from expansion in heating to 212°.

The temperature of steam when not superheated is most easily deduced from the pressure, as shown in a table, marked No. 5, from Rankine; if superheated, a thermometer inserted in the pipe is a convenient mode of ascertaining it; for converting feed water of other temperatures than 212° to an equivalent quantity of that temperature, and for converting steam of other pressures than that of the atmosphere to an equivalent quantity at atmospheric pressure, the annexed table, also from Rankine, marked No. 6, serves to conveniently make the conversion.

As the committee do not recommend the testing of all boilers at one uniform pressure, conversions such as are accomplished by these tables are useful in making comparisons of results from boilers tested under different conditions of feed temperature and steam pressure.

The committee are of the opinion that it is not properly within the province of a scientific association to attempt to adjust commercial standards, nor to engage in the interpretation of contracts between buyer and seller, and have endeavored to show what has been the practice of different parties in making boilers and engines, and what are the requirements in evaporative capacity for producing one horse-power under different conditions, and, in conclusion, respectfully suggest that controversies in such questions are most easily avoided by employing competent engineering skill in selecting and purchasing boilers.

The number of elements that necessarily enter into the successful operation of boilers is so great, that it is unreasonable to look for adequate skill among those not specially educated and practically familiar with the subject.

The computations required to convert different temperatures of feed to an equivalent in a fixed standard temperature, and to convert varying temperatures and pressures of steam into an equivalent in a fixed standard, are not such as persons engaged in mercantile and manufacturing pursuits are conversant with; and whilst there is no mystery surrounding these operations, there are wide differences of opinion between engineers as to the proper basis of calculations for converting thermal units into foot pounds or other dynamic expressions.

This wide difference of view between careful and intelligent experimenters is sufficient to place others on their guard in making calculations of such conversions, and forms a strong argument in favor of stipulating fully and exactly the conditions under which steam boilers are to be operated, and then testing them under such conditions.

W. Barnet Le Van, William H. Wahl,
S. Lloyd Wiegand, Thos. L. Luders.

REPORT NO. 4.

The undersigned members of the Committee on the Horse-power of Steam Boilers, disagreeing with the views expressed in the report presented, ask leave to submit the following report.

After reconsideration of the subject referred to the original committee, no good reason appears for modifying the preliminary or final report of said original committee, in the definite conclusion that the horse-power of boilers for stationary engines and for heating purposes is properly defined as the *capability to evaporate a cubic foot of water per hour from and at the temperature of* 212° *Fah.* This, as stated in our previous report, should be effected with a fair average economy of fuel.

The Committee are confident that three-fourths of all stationary boilers are made and sold upon the basis of "horse-power," although many if not most of them are further qualified by some specification of dimensions which govern and control the *nominal* horse-power of the makers and the purchasers.

Upon inquiry, it seems there is generally attached to the number of horse-power at which boilers are rated, somewhat of the value given to arbitrary numbers in numbering machines of different sizes; but yet *by tradition* some length, diameter, number of flues or of tubes, with sizes of same, size of fire-box, or other particular dimensions, correspond to certain numbers of horse-power in the minds of the makers. In reply to the question as to "what constitutes the horse-power," the general response is referred to the heating surface, which is taken out in very different values for different kinds of boilers, and with sometimes other additions or deductions for supposed efficiency of surface.

Makers have generally an ideal or assumed grate surface, flue area, chimney or other condition appertaining to any of their boilers of a given size, but it does not seem that any definite rules are admitted. With this uncertainty of positive laws of proportion, boilers of any nominal horse-power of any fixed type are supplied by old and known boiler makers, of much the same weight, proportion and capacity. If cross-questioned too closely as to the surface, cubic contents, weights, exposures, *the practical boiler maker* contents himself with the assertion that such and such a boiler is 20, 30 or 50-horse-power, either for buyer or seller.

The relations of buyer and seller in the purchase and sale of a boiler are the offer of so much money by one to pay for material or work by the other, both understanding that the boiler should have certain capability, which is rated as "horse-power."

Nor do the Committee find any reason to modify the nominal value of the horse-power of steam boilers to be based on any supposed improvement of engine, use of higher steam or discoveries of absolute dynamic force of evaporation of water (or heat used in evaporating water).

The average *stationary engine* of America and of to-day does not probably produce a horse-power in impulse of machinery or raising of water, with so little fuel as the average engine of Watt's time.

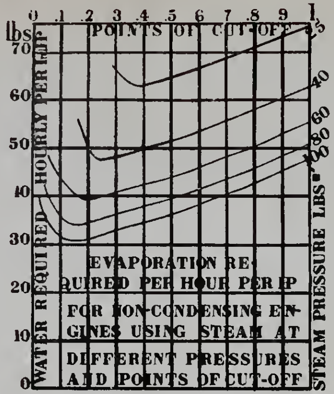
Cheapness of original construction and direction of service without cost of repair, are more studied, as a rule, than economic effect.

High-pressure non-expansion slide-valve engines predominate greatly, and they are far below, in economy of fuel, the condensing engine, worked expansively with double-beat valves, in use in England, where the value of a "horse-power" of the boiler was established.

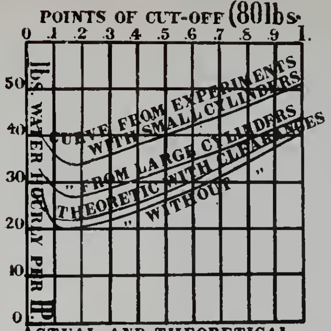
The thermo-dynamic effect of the evaporation of a cubic foot of water from and at 212° is about 23-horse-power, but no practical result coming near that figure has been considered possible.

There can be quoted instances where the *effective or actual* horse-power is produced with the combustion of 2 lbs. of coal per hour, and the Committee can quote one instance in the United States of such performance by 2·13 lbs. of coal (under 2 lbs. of fuel *burned*). This instance is equivalent, with a fair boiler, to the evaporation of less than one-fourth of a cubic foot of water for an *actual* horse-power. Such examples are too infrequent to disturb the general rule. Besides, the purchaser of a boiler by a rating of horse-power expects to receive the boiler that custom has established, and that any special advantage derived from construction of engine or economical use of steam will inure to him. Suppose improvement of engine to reach one-half the theoretical limit, the absurdity of the proposition that a boiler maker could supply the owner of such an engine on a contract for a 50-horse-power boiler, with a 5-horse-power one, is too manifest for discussion.

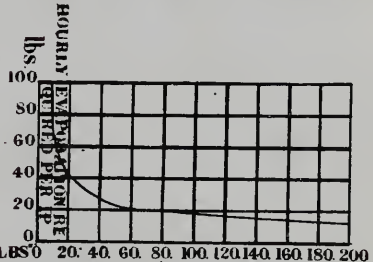
To the further requirements of the Institute, that your Committee shall report directions for ascertaining the quantity of feed-water and its temperature, and the temperature of the steam generated, and the method or figures necessary to reduce the result to equivalent values with feed-water and steam assumed to have been at 212°, so that the



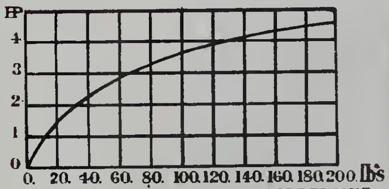
EVAPORATION REQUIRED PER HOUR PER HP FOR NON-CONDENSING ENGINES USING STEAM AT DIFFERENT PRESSURES AND POINTS OF CUT-OFF



ACTUAL AND THEORETICAL EVAPORATION AT 80 lbs. PER SQ." REQUIRED PER HP FOR NON-CONDENSING STEAM ENGINES



VARIATIONS IN W'TS. OF WATER PER HP REQUIRED FOR NON-CONDENSING ENGINE USING STEAM OF DIFFERENT PRESSURES



VARIATIONS IN HP OF NON-CONDENSING ENGINES USING EQUAL W'TS. OF WATER IN STEAM OF DIFFERENT PRESSURES.

NO: 6.

BLG PT.	TEMPERATURE OF FEED WATER FAH.°										
	32	50	68	86	104	122	140	158	176	194	212
212	119	117	115	113	111	110	108	106	104	102	100
230	120	118	116	114	112	110	108	106	104	102	101
248	120	118	116	114	113	111	109	107	105	103	101
266	121	119	117	115	113	111	109	107	106	104	102
284	121	120	118	116	114	112	110	108	106	104	102
302	122	120	118	116	114	112	111	109	107	105	103
320	122	121	119	117	115	113	111	109	107	105	103
338	123	121	119	117	115	114	112	110	108	106	104
356	123	122	120	118	116	114	112	110	108	106	104
374	124	122	120	118	117	115	113	111	109	107	105
392	124	123	121	119	117	115	113	111	109	107	106
410	125	123	122	120	118	116	114	112	110	108	106
428	125	124	122	120	118	116	114	112	111	109	107

NO: 5.

TEMPERATURES IN FAHRENHEIT DEGREES.

212	227	240	250	259	267	274	280	287	292	297	303	308	312	316	320	324	328	331	334	337
0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100

LBS. PRESSURE PER SQ. INCH ABOVE
ATMOSPHERE.

number of horse-power of a boiler can be readily ascertained in accordance with the rule by *practical engineers*, your Committee answers:

1st. The quantity of water.

Having ascertained by the gauge cocks or the glass gauge the level of water at the time of commencing the trial, and having the same level at the moment of completion, the water used can be measured by a meter or in a tank (the capacity of which may be easily computed); or, in the absence of either of these, the supply of the boiler may be taken from any vessel by a temporary connection, which vessel shall be supplied with water from time to time, *weighed in.*

A cubic foot of water at 212° weighs almost exactly 60 lbs. If the temperature of the feed-water is between 45° and 70° (limits rarely exceeded), there is to be added 4¼ per cent. to the measured quantity of water (when it is measured, not weighed) for expansion between the temperature of feed and 212°.

2d. The temperature of feed water and of steam.

The temperature of feed-water can be taken by an ordinary thermometer. That of steam is practicably that of the boiler at any point not far removed from the surface of the water, and can be ascertained by inserting at such a point a well or little open cell of wrought or cast iron filled with mercury, in which mercury bath the bulb of a high temperature thermometer can be inserted. The loss of heat in conduction from the steam to the bulb is insignificant, and the thermometer will indicate, within a fraction of a degree, the proper temperature of the steam.

But the more ready way is to take the temperature as a deduction from the pressure gauge. (Of course it is necessary to have a verified pressure gauge on the boiler in such a case).

The following table gives the temperature corresponding to pressure from that of the atmosphere to 100 lbs. above, varying 5 lbs. The intermediate temperature can be taken out by interpolation:

(After Rankine).

Atmosphere,	5	10	15	20	25	30	35	40	45	50	lbs.
	227	240	250	259	267	274	280	287	292	297	Fah.
	55	60	65	70	75	80	85	90	95	100	lbs.
	303	308	312	316	320	324	328	331	334	337	Fah.

3d. The factor for evaporation, &c.

Having the quantity of water, the temperature of the feed-water and that of the steam, the following table from Rankine gives the multiplier to be used in the several cases:

Boiling Point, Fah.	Initial Temperature of Feed-water.										
	32°	50°	86°	86°	104	122	140	158	176	194	212
212	119	117	115	113	111	110	108	106	104	102	100
230	120	118	116	114	112	110	108	106	104	102	101
248	120	118	116	114	113	111	109	107	105	103	101
266	121	119	117	115	113	111	109	107	106	104	102
284	121	120	118	116	114	112	110	108	106	104	102
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392	124	123	121	119	117	115	113	111	109	107	106
410	125	123	122	120	118	116	114	112	110	108	106
428	125	124	122	120	118	116	114	112	110	109	107

4th. The steam issuing from the boiler should be dry steam.

No rule can be given to judge of this; but the practical engineer, in testing a boiler, will institute such means as he finds readiest to satisfy himself on this point.

The allowance for wet steam and for loss of efficiency of the boiler in this way (and apparent excess of evaporating from this cause) is purely a matter of judgment.

To ascertain the evaporative capacity of the boiler, the trial should be made under the usual conditions of draft and pressure of steam, also of a good quality of coal (anthracite or bituminous), for which the boiler is designed.

The boiler being put up to its working pressure, the fire should be clean, and at an average level at the time of starting, and be at the same level and condition at the conclusion. The ashes and clinkers in the ash-pit must be deducted from the coal used.

Another and more certain plan is to have the boiler up to its working pressure, draw the fire, and fire up with enough wood to kindle and fresh coal both weighed in, and at the conclusion draw the fire, and weigh refuse ashes, clinkers and coal, for deduction. In this case, the evaporative capacity of the boiler should be estimated from the time the fire is bright, but for the economy, the total water evaporated from the commencement is to be divided by the total weight of combustible used minus the refuse.

The trial, if accuracy is desired, should not be less than of ten hours' duration. A longer trial would reduce the uncertainties to a smaller proportion.

Edwd. Brown,
John H. Cooper,
Robt. Briggs.

Philadelphia, Oct. 15, 1873.

ON A NEW HYDRAULIC RAILROAD CAR BRAKE.

By William M. Henderson, Philadelphia.

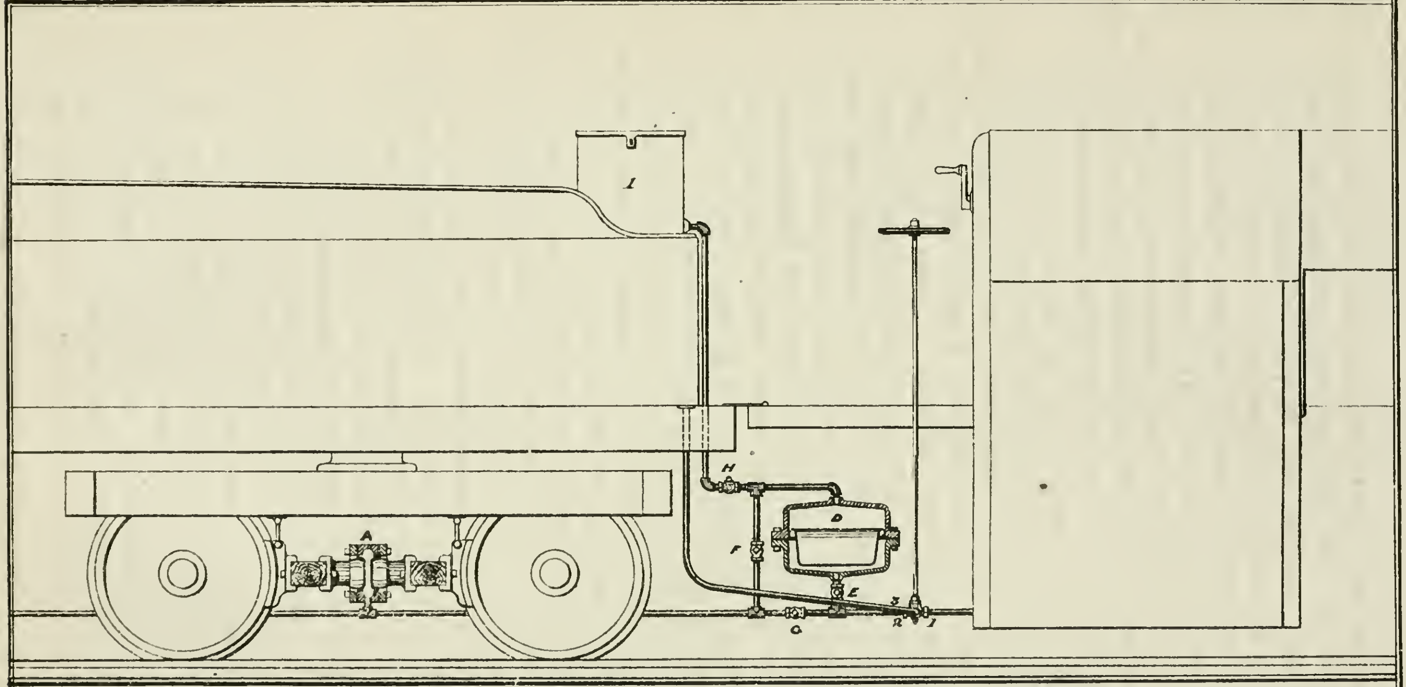
A paper read before the Franklin Institute Oct. 15, 1873.

The principle involved in the operation of this brake is that of hydraulic pressure, and the motive power is derived directly from the steam-boiler of the locomotive, and under the control of the engineer.

There is first a three-branch or two-way cock placed underneath the foot-plate of the engine, its plug actuated by a stem carried up through the foot-plate, and furnished with a horizontal lever at top, carrying an index pointer, traversing a quadrant plate marked *on* and *off*, with gradation marks between, as a guide to the engineer in operating the brakes; and there is also a small pressure gauge, placed conveniently before him, to show him the pressure he is applying. The nozzle of the cock, marked 1, is connected by a short piece of wrought iron pipe directly to the water space of the boiler; the opposite nozzle, marked 2, is connected by wrought iron pipe and flexible hose connections, furnished with valvular couplings between the cars, as usual in such cases, and leads directly to pressure boxes placed between the brake beams of each truck; the third nozzle, marked 3, is connected directly to the water tank supplying the boiler with water.

The construction of the pressure boxes is as follows: A cylindrical vessel of cast iron is furnished, having flanges at either end; it is about 9 inches in diameter and 3 inches deep, the inner diameter being about 5 inches. Two flexible dish-shaped diaphragms are next introduced, back to back, having about half an inch space between them, and are secured in position by rings bolted firmly to the drum, making an air-tight joint. Into the interior of the dish-shaped diaphragm are fitted two rams, working in opposite directions; these are bolted by rectangular flanges to the centre of the brake beams, carrying the brake shoes. Guide rods are also provided to support the drum in position relative to the rams; these are simply two pieces of ¾ round iron, passing through lugs cast on the two sides of the drum and through the flanges of the rams.

The operation of this apparatus is as follows: Steam being up in the boiler, and the connections of the main pipe being all coupled between the several cars, the engineer will turn the plug of the two-way cock so as to establish a communication between the water tank and the main, as shown by fig. 4. He then passes to the rear end of the train, and opens a small air-cock placed at the extremity of the main, and allows the water to travel to that point. This it will do by virtue of the head of water contained in the tank. When the air is expelled the engineer will close the cock, return to the engine, and is then prepared to start. We will now suppose the train in motion, and it is desired to apply the brakes. The engineer will simply turn the plug of the two-way cock so as to make a communication between the boiler and the main, as shown by fig. 5. It will be observed, in doing this, he will have shut off all communication with the water tank. Now, then, the pressure within the boiler will exert itself upon the water column, and produce a hydro-dynamic pressure equal to the boiler pressure upon each square inch presented by the area of the rams, when turned on full head; or the pressure to be applied can be varied by partially opening the cock; or a special provision can be made in the shape of the valve openings, so as to produce such graduated result. Taking the usual pressure carried on our locomotive boilers, 120 lbs. per square inch, and applying this pressure to our 5-inch rams, we have above 2800 lbs. of force brought to bear upon each pair of wheels. To take the pressure off the brakes, the plug of the two-way cock is turned back to its original position, opening a communication again with the water tank, as shown by fig. 4. This shuts off all communication with the boiler, and of course destroys the hydraulic pressure. The diaphragms being thus relieved will recover their normal condition by reason of their own elasticity, and the beams carrying the brake shoes will be thrown off the wheels by the springs invariably provided for that purpose. The surplus water will then be discharged into the water tank, preventing any waste either of water or heat, becoming a part of the feed-water to



HENDERSON'S PATENT, HYDRAULIC RAILROAD CAR-BRAKE.

HENDERSON, DEL^t

PHOTO-LITH, BY A. DICKES, 125 SOUTH FOURTH ST PHILA.

be returned to the boiler. There are stops obviously arranged between the body of the two-way cock and its plug, in such manner that the plug can never be turned so as to open a communication between the steam-boiler and the water tank. In order that the force of applying the brakes shall not be of an objectionable concussive or jarring nature, two means have been provided: *first*, an air-vessel placed on top of the pressure boxes, which will furnish a cushion of air to absorb it; and, *second*, springs of rubber or other elastic material placed between the brake beams and the shoes to relieve it.

The above-described apparatus is all that will be required to efficiently equip a train of cars south of Mason and Dixon's line, and will be equally efficacious for about nine months in the year in the Northern States. To adapt this invention for low temperatures, the following device is made attachable:

A cast iron cylindrical vessel is provided, of a capacity to contain sufficient non-freezing fluid to charge the maximum number of pressure boxes usually employed on a train of cars. It is made in halves, and embraces at the joint, where it is bolted together, the flange of a double corrugated flexible diaphragm, making an air-tight joint. The fluid to be used for operating the brake pressure boxes is placed above the diaphragm, and the pressure from the boiler is applied below. As the pressure on either side will be the same during its operation, the medium is therefore a mere separator, preventing the fluids on either side of it from commingling. For the non-freezing fluid, glycerin and water in equal parts is preferred, which is safe to about 30° below zero. (Glycerin itself never freezes). The glycerin chamber is connected to the main by a short tubular connection, furnished with a stop-cock, E. Leading away from the other end of this chamber is another tube connection, making an advanced connection with the main, and is also furnished with a stop-cock, F. Between the point of junction of these two connections there is placed another stop-cock, G. When the cocks E and F are shut and G opened, the brakes will be operated entirely by water from the tender tank. When the cocks E and F are opened and G is shut, whatever fluid is used to operate the brakes must come solely from the glycerin chamber. The pressure from the boiler, acting upon the underneath side of the diaphragm, will cause a discharge of the fluid to operate the diaphragm of the pressure boxes, as before; and when the brakes are let off this fluid will return to the glycerin chamber, the diaphragm making room for it by adjusting itself to its normal state, and the water under pressure will be delivered into the tender tank precisely as previously described. In order that the glycerin chamber shall remain at all times fully charged with fluid, a tank or reservoir is provided on the tender, containing an excess quantity. The pipe proceeding from this tank to the glycerin chamber has a check-valve fitted to it, opening towards the glycerin chamber, so that this result must be fully accomplished; for, if a vacuity should occur in the glycerin chamber from loss by accidental leakage, the loss will be immediately made good from the reservoir, while a disposition for any of the fluid to return is instantly checked by the closing of the check-valve.

This brake can be applied equally well to the outside of the wheels, and is adapted to any kind of truck, either four or six-wheeled.

As compared to other brakes, the saving effected consists in doing away with the steam-pump and receiver, all cylinders, pistons, stuffing-boxes, lever-rods and springs, all packing, lubricating, and a total exclusion of dust.

BELTING FACTS AND FIGURES.

By J. H. Cooper.

(Continued from page 329.)

The following notes on belting are taken from Mr. B. F. Sturtevant's illustrated catalogue of Pressure Blowers, Boston, Mass. :

"Double Belts are calculated to be one-third of an inch thick, single belts one-fifth of an inch thick. The holding power of the belt is governed wholly by its tension or tightness and the condition of its surface, the diameter of the pulleys having nothing to do with it, and is capable of being increased by tightening to 350 pounds to 1 square inch of cross section.

"As a general rule, belts running from a large to a small pulley, slip on the large and not on the small one, as is commonly supposed. This is explained as follows: The pressure per square inch with which the belt hugs the small pulley is just as much greater as the small pulley is less in diameter than the large one, and the friction of the belt more than follows the increased pressure. For example: If you cover the small pulley on the counter with leather, to prevent slipping, you must also cover the driving pulley on the main line, or you get no benefit from covering the small pulley. These remarks apply to horizontal belts.

"A table is given for finding the width in inches of double main belts for driving his patent pressure blowers, which is based on the statement that a belt, one inch wide, having a velocity of 1000 feet per minute, will give one horse-power. This is also equivalent to a surface velocity of $83\frac{1}{3}$ square feet of belt per minute per horse-power, and a working strain of 33 pounds per inch width of double belt, or 99 pounds per square inch of cross section of leather.

"New belting, such as is generally used for the driving belts, on polished iron pulleys, will only transmit from one-third to one-fifth the power, without slipping, that the same belt will after it has been in use from one to two months.

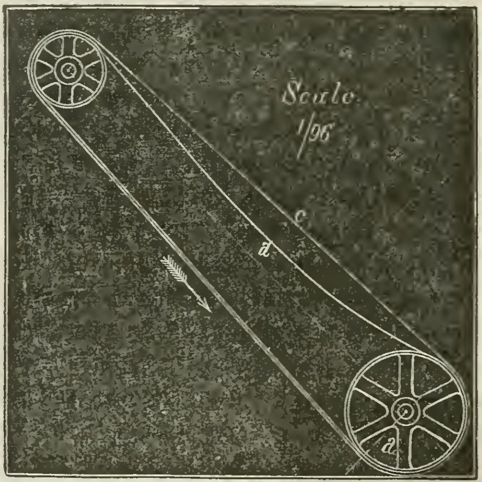
"The belts for driving the blowers are not exposed to the wear and tear of shippers as lathe belts are; all of them run over small pulleys in proportion to the width of the belts. Hence I have recommended a scale of thicknesses of belts in proportion to the widths; the lighter the belt the tighter it hugs the pulley, for the reason that all unnecessary weight of leather tends to lift itself off the pulley when going around it at a great velocity, and some of these belts travel at a velocity of 5000 feet per minute.

"Belting, as it is generally manufactured, as an article of merchandise, is intended for all purposes for which belting is used; but when parties are desirous of having everything about the blower just as it should be, they will see that their belts are made exactly to suit their work.

No. of fan.	Diam. of pulley.	Face of pulley.	Breadth of belt.	Thickness of belt.	Revs. of fan per min.	Diam. driving pulley.	H. P. required.
00	$1\frac{7}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	·08		21	
0	$2\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{1}{2}$	·09		21	
1	$2\frac{5}{8}$	2	$1\frac{3}{4}$	·11	4135	21	·5
2	3	$2\frac{3}{8}$	2	·12	3756	24	·1
3	$3\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{3}{8}$	·13	3250	28	1·8
4	$4\frac{1}{4}$	$3\frac{1}{4}$	$2\frac{3}{4}$	·15	3100	32	3
5	$4\frac{7}{8}$	$3\frac{7}{8}$	$3\frac{1}{4}$	·16	2900	36	5·5
6	$5\frac{3}{4}$	$4\frac{1}{2}$	$3\frac{7}{8}$	·18	2820	42	9·7
7	$6\frac{7}{8}$	$5\frac{1}{8}$	$4\frac{1}{2}$	·20	2600	48	16
8	$7\frac{7}{8}$	6	$5\frac{1}{4}$	·22	2270	54	22
9	$9\frac{1}{8}$	$6\frac{7}{8}$	6	·24	2100	48	35
10	$10\frac{1}{4}$	8	7	·25	1815	54	48

"In the above table all the dimensions are in inches. To give some idea of the proper length of belt, the centre of the driving pulley is placed $3\frac{1}{2}$ times its diameter from the centre of the fan, and two and one-seventh times above it. The driven pulley on the driving pulley shaft is 18 inches diameter, and that in turn is driven by a 54-inch diameter pulley and belt of double thickness. The centres of the 54-inch and 18-inch pulleys are placed about three times the diameter of the larger pulley apart, and nearly at same height from floor.

"A curious performance of a pair of belts is presented in the following: The driving pulley *a* on the engine shaft is 5 ft. diameter and runs 75 revolutions per minute; the driven pulley *b* on the line shaft is 3 ft. diameter and about twenty feet distant in a line near 45° with the horizontal; both pulleys are wooden drums covered with leather, and have sufficient breadth of face for two 12-inch belts. When this arrangement was started two 12-inch single leather belts were put on side by side, and for some time were run in that way, but never satisfactorily. After many fruitless efforts to obtain a uniform action of the two belts, one accidentally mounted the other, the two running thenceforth as one double belt; in this way they drove the line shaft better than ever before. Many experiments were tried in the relative tightness of the two belts, which invariably proved that the best driving was always secured when the inside belt *d* was very slack, sagging say 12 to 18 inches, and the outside belt *c* quite tight; the working sides, of course, running close to each other, as shown in the cut. This was in use some 30 years ago in a factory near this city."—J. S. Lever, Philada.

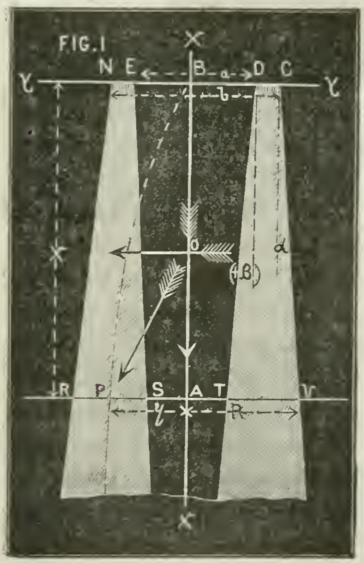


THE STABILITY OF TOWERS AND CHIMNEYS.

By C. A. Evans, Civil Engineer.

This subject has not been treated in the standard works on construction with the detail of which it is susceptible. Many points relating to it are here, the writer thinks, presented for the first time, and especially that portion referring to circular sections.

The stability of vertical shafts of masonry is tested by the pressure of the wind during hurricanes. As usually constructed, these shafts have a batter on the outside and are carried up on the inside, particularly in the case of chimneys, in a series of steps. The latter measure but a few inches in width, and should be so arranged that a batter line may pass through their reëntrant angles. Hence the more numerous the steps, the nearer will they approach in effect to a regular batter. Such a batter, though desirable, yet is not introduced with the view to save workmanship. A chimney, consequently, is divided by the steps into a series of divisions, the thickness of each of which is constant when brick is the material employed. In the following investigation we will consider the steps to be replaced by the batter line passing through their reëntrant angles, and the small amount of material lying outside of this line will, therefore, not be regarded. Its influence, which is at most but very small, is to increase the stability slightly above what will be determined.



In plan, masonry shafts are generally square or round. Octagonal and kindred sections, though given sometimes to chimneys and towers, yet approach so nearly practically to circular sections, that these may be substituted for them.

In what follows we will let, Fig. 1:—

$x = \overline{B\,A} =$ height of any portion measured from the top.

$y = \overline{A\,P} =$ distance from the axis at which the line of resistance cuts the lower section.

$a = \overline{\text{E D}} =$ diameter or side of the opening at top.

$b = \overline{\text{N C}} =$ external diameter or side of the chimney at top.

$p =$ pressure of the wind per sq.ft. on a flat surface.

$u =$ weight of material per cu. ft. $\text{R} =$ radius of any section in the circular chimney.

α and $\beta =$ outside and inside batter respectively.

In the figure $+ \beta$ is shown, and $- \beta$ would be shown by the batter lying on the other side of the vertical, thus making it analagous to the outside batter; which position it usually occupies in large chimneys. The condition $\beta = o$ makes the inside of the shaft vertical; its usual direction in light-houses. We will consider first the shaft with a

Square Section.

For the solidity of any portion of the chimney or tower we have from the fig.:—

$$\overline{\text{NCVR}} - \overline{\text{EDST}} = \frac{(b + 2\,x \tan \alpha)^3 - b^3}{6 \tan \alpha} - \frac{a^3 - (a - 2\,x \tan \beta)^3}{6 \tan \beta}$$

For the distance of the centre of gravity of any section $\overline{\text{N C V R}}$ from $\overline{\text{R V}}$ or its base, we deduce:—

$$\overline{\text{A O}} = \frac{x\,(3\,b + 2\,x \tan \alpha)}{6\,(b + x \tan \alpha)}$$

And for the pressure upon this section:—

$$p\,x\,(b + x \tan \alpha)$$

Finally, by taking the moments around the point P, we have for the equation of the line of resistance:—

$$y = \frac{\frac{p}{u}\,x^2\,(3\,b + 2\,x \tan \alpha)}{\frac{(b + 2\,x \tan \alpha)^3 - b^3}{\tan \alpha.} - \frac{a^3 - (a - 2\,x \tan \beta)^3}{\tan \beta.}} \qquad (1)$$

We will pass now to the

Circular Section.

The expression for the solidity of any portion is in this case:—

$$\overline{\text{NCVR}} - \overline{\text{EDST}} = \frac{\pi\,(b + 2\,x \tan \alpha)^3 - \pi\,b^3}{24 \tan \alpha.} - \frac{\pi\,a^3 - \pi\,(a - 2\,x \tan \beta)^3}{24 \tan \beta.}$$

To obtain an expression for the pressure on the surface of the shaft exposed to the wind, we have for the pressure at any point N of it, Fig. 2:—

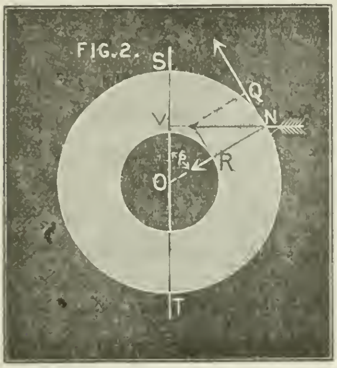


FIG. 2.

$$p \, R \, d \, \varphi \sin \varphi,$$

and this is in the direction N V. Resolving this pressure into two others, one tangential and the other normal to the surface at N, we have for the latter or effective pressure:—

$$p \, R \sin^2 \varphi \, d \, \varphi,\text{—}$$

and, therefore, we may write for the total pressure on $\overline{\text{S N T}}$,

$$p \int_0^{\pi} R \sin^2 \varphi \, d \, \varphi,\text{—}$$

which, by multiplying by $d\,x$ and substituting the value of

$$R = \frac{b}{2} + x \tan a,$$

becomes the pressure on the entire portion x of the chimney:—

$$p \int_0^x \left(\frac{b}{2} + x \tan a\right) d\,x \int_0^{\pi} \sin^2 \varphi \, d \, \varphi$$

The second integral being equal to $\frac{1}{2}$ (φ—cos φ sin φ), we have by taking it between the limits indicated and completing the integration of the expression,—

$$\frac{\pi \, p \, x}{4} (b + x \tan a)$$

On examining this expression, we perceive that it equals a pressure of $\frac{\pi \, p}{4}$ uniformly distributed over the sectional area $\overline{\text{N C V R.}}$ Hence the centre of this pressure is at O, as in the case of the square chimney. Or, by multiplying the preceding integral by x and integrating, we obtain the moment of the total pressure around the axis of y. This, divided by the pressure, will give the lever arm $\overline{\text{B O}}$: from which the length of $\overline{\text{O A}}$, as previously found, may be deduced. Consequently, we obtain for the equation of the line of resistance by taking the moments around P:—

$$y = \frac{\frac{p}{u}\, x^2\, (3\, b + 2\, x \tan \alpha)}{\frac{(b + 2\, x \tan \alpha)^3 - b^3}{\tan \alpha.} - \frac{a^3 - (a - 2\, x \tan \beta)^3}{\tan \beta.}}\,, —$$

Which is identical with eq. (1), in the case of the square chimney. We therefore conclude that *the lines of resistance in a square and in an equally high circular shaft are identical in shape and position, provided the diameters of the one are equal to the sides of the other.* This is accounted for by the peculiarity of the round tower, though containing less material, being subject also to a lesser pressure. As far as regards the amount of material, and under similar conditions, a circular section is preferable to a square section.

The value of y may be written for either section, in terms of the diameter or side of it:

$$y = q\, (b + 2\, x \tan \alpha). \tag{2}$$

In which q represents a fraction, or coefficient of stability, that locates the line of resistance, and consequently determines the stability of the shaft. At the *lowest section, or base* of the shaft we may assume $q = \frac{1}{3}$ for square, and $q = \frac{1}{4}$ for round shafts. In the round shaft it is well to keep the line of resistance a little further in than in the square one; for the outer edge in the former is not as extensive and strong as in the latter. Nevertheless, the foregoing values of q for the base admit of a fluctuation, but of not more than *six hundredths* one way or the other. In the one case we would increase the stability of the shaft beyond necessity, and in the other case we would diminish it too much. The values of q as given may be considered as mean values, and should, therefore, be used in constructing new works. In determining the stability of shafts already built, however, if their values of q at the base lie within the limits indicated, they may be regarded as well constructed. If these values pass one limit they may be considered as unnecessarily heavy, and if they pass the other limit, they should be strengthened.

Having equated eqs. (1) and (2), substituted for x the entire height of the chimney, and assumed the proper value of q, the value of b, $\tan \alpha$ or $\tan \beta$, may be deduced from the resulting equation according to the rest of the quantities assumed. After this unknown is determined, it remains to ascertain the position of the line of resistance. For this purpose values of x are assumed, commencing with 0, or at the axis of y, and increasing gradually by 20, 30, 40 or 50 ft., according to the height of the shaft; and then deducing the corresponding values of y. In order to plot the line, a drawing of the shaft should be made in which the horizontal scale is exaggerated five or ten times. The advantages of such an exaggeration are, that we obtain a small drawing, easily handled; that the curvature of the line is intensified, thus making it more perceptible, and that the horizontal distances can be accurately measured in locating the section of least stability. The portions of the line of resistance included between the joints determined, may be sketched in with ease and correctness. The joint of least stability is indicated, not by where the line approaches nearest to the outside of the shaft, but by where this approach is nearest in proportion to the distance to the axis of the tower from the line. This ratio of the inner to the outer segment of the half section containing the line of resistance, is ∞ at the top, diminishes very rapidly as we descend, becomes a *minimum* at the section of least stability, and finally when $q = \frac{1}{4}$ or $\frac{1}{3}$ increases at the base to 1 or $\frac{1}{2}$. The value of ∞ at the top shows that the shaft there can never be overthrown. Evidently this is the case, for the line of resistance coincides there with the axis of the shaft. Such a ratio as the foregoing may be regarded as a coefficient of stability, which it really is. The stability of all the sections may also be determined in the same manner as that of the lowest section, that is, by deducing the values of q for them. But this process is much more laborious than the one we have described. The joint of least stability, indicated by the maximum value of q, is obtainable mathematically by substituting eq. (2) in eq. (1), and differentiating. The resulting equation, however, is too long for practical use, and can be solved conveniently only by the tentative process. The joint of least stability is generally in the larger shafts at about half of their height above the base, but in small shafts it descends sometimes as low as a few feet above the ground.

The greatest pressure of the wind is taken in Great Britain at 55 lbs. to the square foot. Unfortunately, we have no records as to the maximum pressure experienced in these latitudes, and in fact in not any latitudes accurately. The experiments of Smeaton are the only ones given in scientific works. The writer is inclined to think that no hurricane presses here with a greater violence than 45 lbs. to the square foot, an enormous pressure when well appreciated, and that this figure would suit most localities on both continents. Yet in view of the uncertainty on this point, he would recommend, on the ground of safety, the English practice of using 55 lbs. for the greatest pressure of the wind per square foot. This is a figure which he has himself employed with economical results.

In the case of light-houses, the portion not exposed to the shocks of waves during storms may be calculated by the foregoing principles. The lower part may be formed either as a pedestal sufficiently massive to resist the greatest violence of the sea, or in a monolythic mass by the usual means.

We will illustrate the preceding investigation by an example, and shall choose the St. Rollox chimney as an instance well known. As actually constructed, this shaft has a variable batter on the outside, which differing *very little* from a straight batter, may be considered quite properly as such. On plotting the chimney and drawing a batter line as near as possible through the reëntrant angles of the steps on the inside, we deduce the following data to obtain the value of tan α:

$$a = 11.9', \; b = 13.5', \; \tan \alpha - \tan \beta = .004'.$$

The total height = 435.5′, the pressure of the wind per sq. ft. = 55 lbs. = p, and the weight of a cu. ft. of brickwork we will take = 118 lbs. = u. We know also the thickness at the base, which is:

$$435.5 \times .004 + \tfrac{1}{2}(13.5 - 11.9) = 2.54'.$$

We have by substituting in the equation, changing the sign of tan β, and assuming $q = \frac{1}{4}$:

$$y = \frac{\frac{55}{118}\, 435.5^2 (40.5 + 871 \tan \alpha)}{\dfrac{(13.5 + 871 \tan \alpha)^3 - 13.5^3}{\tan \alpha} + \dfrac{11.9^3 - (11.9 + 871(\tan \alpha - .004))^3}{\tan \alpha - .004}} = \tfrac{1}{4}(13.5 + 871 \tan \alpha).$$

This equation reduced leads to:

$$1276.5 \tan^3 \alpha + 1498.5 \tan^2 \alpha + \tan \alpha - 2.05 = 0.$$

From which, by a few trials:

$$\tan \alpha = .036.$$

The other two values of tan α are negative, as indicated by the sign of 2.05. Knowing tan α, we have for the diameter of the base, 44.86′. This diameter, as actually built, is only 40.00′. The cause of the discrepancy we will investigate further on, and proceed now to determine the position of the line of resistance. With this object in view we will assume $x = 100$, $x = 200$ and $x = 300$, and deduce from eq. (1) the corresponding value of y:—

$$y = 5.7, \quad y = 8.7, \quad y = 10.6.$$

We have, therefore, with the points at the summit and base of the shaft, altogether, five points of the line of resistance in order to draw it in. In actual practice, we would need a few more to produce accurate work. These should be obtained in the neighborhood of the joint of least stability. However, with our data this joint is found to be about 200 feet from the top of the chimney.

The discrepancy noticed above indicates only that the value of q is a little larger than 0.25, at which we assumed it. To determine it accurately, we substitute in equation (1), in addition to the foregoing data, the value $\tan \alpha = .0304$ taken from the plot and solve it with respect to y. We thus deduce:—

$$y = 11.41' \quad \therefore \quad q = 0.285.$$

As this value of q falls considerably within the limits set down, we may therefore feel assured of the stability of this elegant construction.

Many engineers, in order to save some material, may be tempted to use q as large as possible, and surpass the limits we assigned to it. But let it be remembered that we should provide sufficiently against any obliquity in the axis of the shaft, resulting from imperfect workmanship, from any irregular compression in the foundation, or from any unequal settlement in the lower joints, caused by the shaft being built too fast. Provision must also be made, by keeping in the line of resistance, against the compressive strength of the material on the outside of the shaft being tested beyond its endurance, which will be fully tried when the shaft is put in vibration by a succession of hard blasts of wind. This remark applies particularly to brick and the softer stones. In conclusion, we may notice that the strength of an intended shaft may be increased either by augmenting the base or the thickness of the shell. Of course, the augmentation in either direction is limited by other requirements, and is not indefinite.

Chemistry, Physics, Technology, etc.

ON SOME RECENT IMPROVEMENTS IN THE MANUFACTURE OF ARTIFICIAL STONE, AND THE APPLICATION OF SUCH STONE TO CONSTRUCTION AND OTHER PURPOSES.

By Frederick Ransome, Esq. C. E.

(A Paper read before the Franklin Institute, November 10, 1873.)

Being on a visit to this country with a view to the introduction of a process for the manufacture of stone, which has been successfully employed in England and in other parts of the world, the author has been kindly invited to read a short paper upon the subject at this Institute.

It may be desirable at the outset to state that it is not the object of this paper to treat of the many various methods for making artificial stone which have from time to time been brought before the public; their name is legion, and their several natures and properties have already been dealt with by abler and perhaps more disinterested investigators. Therefore, whilst recognizing peculiar merit in many of such methods, and appreciating advantages they have severally afforded in the arts, both of construction and ornament, when properly applied, the author will allude more particularly to those in which he is more directly interested, to the perfection of which he has devoted the greater portion of his life, and which he believes are, in most respects, essentially different, both in the details of their manufacture, and in many of the various purposes for which they are especially designed.

The progressive development of the natural world, through periods which occurred long before the dawn of the most remote traditions of antiquity, have placed at the disposal of man materials which for the most part eminently subserve the various purposes of construction and decoration. These materials, however, such as the granites, marbles, sandstones, limestones, so occur in isolated groups, in some instances so remote from the centres of civilization, the cost of labor in working into form, and the consequent waste of the material itself so great, as to render them prohibitable for general use, except in local situations.

The requirements of man soon demanded a material which should approximately fulfil the conditions of stone in the construction of their buildings, and this necessity was in the earlier ages supplied to a great extent by the manufacture of bricks, concrete, etc.

The advantages afforded by these substances were readily recognized by the ancients, and have been fully appreciated in modern times; but great as these advantages are in a constructive point of view, they fall very far short of the requirements of the present age. It is therefore no matter for surprise that numerous attempts have been made from time to time to supersede or supplement the productions of nature by the imitations of art, and the importance of producing a material combining all the merits, without having the defects, of the most useful building stones, and at the same time possessing advantages peculiarly and specifically its own, was long since recognized by the author, and he adopted the task of solving the problem of manufacturing a stone which should economically answer, at least, some of the varied purposes of the products of nature.

He commenced his investigations into the nature and properties of stone just thirty years since, and he found, that with comparatively few exceptions, the hardest and most durable were those in which silica abounded, either in the form of quartz or crystals, or in combination with lime or other substances. With this fact in view, he commenced a series of experiments, and selecting silicious sand (composed of crystals of nearly pure quartz, and which may be obtained in abundance in almost all parts of the world) as a base, he proceeded to combine the particles by the admixture of a small proportion of powdered glass and clay under hydraulic pressure, and subsequently more completely uniting the mass by partial fusion. After numerous unsuccessful attempts, and after having, as he believed, exhausted the various combination of sand, etc., with almost every known cement within his reach, it occurred to the author to substitute a concentrated solution of silicate of soda or potash for the other cementing materials he had previously employed. Sand, when mixed with this solution 'of silicate of soda or potash, and pressed into a mould, formed, when dried, a very hard stone, having a close and uniform texture, but which, however, became disintegrated upon being exposed to moisture. The next step was to submit the compound to the action of heat, when the free alkali of the cementing silicate, combining with an additional quantity of the silex of sand, produced an insoluble silicate unaffected by moisture. The author obtained his first English patent for this process in 1844, and immediately established works for the manufacture of what was then known in the market as the "Patent Silicious Stone." Such were in general the results obtained and such, with various modifications in points of detail, was the process adopted by the author in manufacturing stone for many years.

The stone thus prepared was found to be very hard, of beautiful texture, and perfectly indestructible by atmospheric influences or acid vapors. Many illustrations confirmatory of this statement may be seen at the present time, where the "Patent Silicious Stone" has been exposed to the most vitiated atmosphere in London, the finest edges and tool marks upon which are still as sharp as when they first left the manufactory. There were, however, serious practical objections to this mode of manufacturing, which will at once occur to the minds of many present—the operation was at once both tedious and expensive. Special care and considerable time had to be taken to drive off all superfluous moisture before the articles were placed in the kiln, in which the heat had to be generated and reduced very gradually; the risk of flaws and of cracking formed a very serious item in the process, and after all care and expense which could be expended to prevent the failures alluded to, it was found to be practically impossible to secure truth of outline, or, in other words, to prevent distortion by the expansion and contraction produced in the process of burning. The next problem was to determine how to convert the soluble silicate of soda into some insoluble silicate, which should possess the properties requisite for the formation of a good, hard, compact and durable stone without the action of fire heat, which had been found so inconvenient and expensive in the former methods.

In the year 1856 the author secured letters patent in England for a means of rendering stone, bricks and other building materials less liable to decay by first saturating these with a solution of silicate of soda, and afterwards applying a solution of chloride of calcium, which immediately decomposed the former, and produced an insoluble silicate of lime in the stone, etc., so operated upon; and in the year 1861, in consequence of the premature decay of the stone of the new Houses of Parliament at Westminster, a special committee was appointed by Government to examine and report on the causes of such decay and the best means of preserving the stone from further injury. The author, in common with others, was summoned to attend, and give evidence on the subject; and after stating the satisfactory effects produced upon the stone of some of the buildings upon which he had operated, he proposed that, in order to demonstrate more conclusively the efficiency of the process, that a piece of the stone should be reduced to powder, and then, by the aid of the two solutions of silicate of soda and chloride of calcium, to reconvert the powder back into a solid stone.

The experiment was tried, and the result was so completely successful that the author immediately applied for a patent for the manufacture of stone by the employment of the above and similar ingredients, which patent was accordingly sealed in England on the 3d of October, 1861. Arrangements were at once made for the manufacture of stone upon a large scale by this process, which, in order to distinguish it from the "Patent Silicious Stone" already described, is called the "Ransome Patent Stone." This material, in which sand and silicate of soda, etc., after being thoroughly incorporated in a suitable mixing mill and moulding into the form required, is saturated with a concentrated solution of chloride of calcium, by exhausting the air by means of air pumps, or by forcing the solution through the moulded mass by gravitation or otherwise. Double decomposition of the two solutions immediately takes place, resulting in the production of an insoluble silicate of lime, firmly uniting and enveloping all the particles of which the mass is composed, and a solution of chloride of sodium or common salt, which is subsequently removed by the free application of water. This description of stone has now been extensively used in England during the past twelve years, and the demand for it is very rapidly increasing for all kinds of building details, especially for those of an ornamental or artistic character. It is perfectly free from all liability to distortion or shrinkage, is unaffected by any variations of climate or temperature, and is uniform and homogeneous in its texture. It has been most successfully employed in various countries abroad, especially in India, where the Government has established works for its manufacture. It has also been employed to a considerable extent in this country, especially in Chicago and San Francisco, where it is successfully manufactured. There are upon the table several specimens of this stone which were manufactured at the works of Messrs. Wright & May, at Chicago, and which bear a very favorable comparison in appearaace with the best descriptions of the natural stones of this country. Its cost is less than half that of natural stone in details of an ornamental character, especially where there is much repetition, and its enduring quality is now so fully established as to need no comment.

When the author visited Chicago a few weeks since, he inspected several buildings which have been erected since the calamitous fire of 1871, faced entirely with the Ransome stone, manufactured by Messrs.

Wright & May, which may easily be mistaken, by a casual inspection, for the marble of the district, and he was informed, upon reliable authority, that there were about two hundred buildings in the city in which the "Ransome stone" had been employed for dressings or finishings, and although the thermometer was as low as 27° below zero during last winter, it stood perfectly uninjured.

Dr. Ed. Franklin, in writing upon the Ransome stone, says, "I am induced to believe that Mr. Ransome has invented a material which, with the exception of the primary works, is better capable of giving permanency to external architectural decorations than any stone hitherto used."

Dr. A. Snowden Piggot, Analytical Chemist, Baltimore, says—"Double decomposition ensues, and a silicate of lime of a glassy hardness and imperviousness coats every grain and binds the whole into one solid mass. Such a stone carefully made may be considered proof against all ordinary atmospheric influences."

Professor Ansted states—"A parallel bar of Ransome's stone, 4″ × 4″, resting on iron frames so as to bear one inch at each end, with sixteen inches clear between the supports, sustains a weight suspended from the centre of 2122 pounds. A 4-inch cube of Ransome's stone sustained a weight of thirty tons before it was crushed."

One more special application in which the Ransome stone has proved eminently successful may suffice, viz., in the manufacture of grindstones, which surpass in their cutting properties all those of the natural stone in comparison of which they have been tested.

With a view fairly to test the comparative grinding power of these stones, Messrs. Donkin & Co. constructed a simple apparatus by means of which an equal and uniform pressure could be exerted upon pieces of steel presented to the faces of the several grindstones. The pieces of steel were cut off the same bar, and were accurately weighed before the operation; the grindstones were then set in motion. The Newcastle stone ground away a quarter of an ounce of steel in eleven hours. The "Ransome stone" ground away a quarter of an ounce of steel in sixteen minutes. The same description of stones are now largely used in England for shelling and cleaning rice, and for grinding and rubbing purposes generally, and are exported to all parts of the world.

The foregoing is a brief history of the material manufactured by the author down to 1870, at which time he developed another process as distinct from the last described as was that from the one patented by him in England in 1844; and for which he obtained another patent in England in October, 1870, and a subsequent patent in the United States in 1872. This latter process, for the sake of distinction, is called "Ransome's Apœnite."

It was found in practice that the process of washing the "Ransome stone" so as completely to remove all trace of the chloride of sodium from large masses, was open to objection; it was both tedious and expensive, especially in localities where there was a difficulty in obtaining a good supply of tolerably pure water at a reasonable cost; besides which, in producing so large an amount of chloride of sodium, which had to be afterwards removed from the stone as a waste product at considerable cost, the bulk of the alkali, which was by far the most expensive ingredient in its composition, was ejected instead of being utilized, for still further increasing the density, strength and hardness of the stone.

This defect had for a considerable time engaged the attention of the author with the view of effecting a remedy, and step by step it has been accomplished by a process so simple and in a manner so satisfactory in its results, as to leave little or nothing to be desired.

Some years since a silicious deposit was discovered at the base of the chalk hills in Surrey, possessing some very peculiar properties, amongst others, that of being readily soluble in a solution of caustic soda or potassa, at a moderately low temperature.

Taking advantage of this peculiarity, the author commenced a series of experiments, in order to determine if it were not possible, without the use of chloride of calcium, to produce a stone in all respects equal in quality to what had hitherto been made, and in this he has now succeeded, by mixing, in lieu of the chloride of calcium, suitable quantities of lime (or substances containing lime) and the natural soluble silica above alluded to, with sand and a solution of silicate of soda or potassa, which, when intimately incorporated, are moulded as heretofore, and allowed to harden gradually as silicate of lime is formed by the decomposition of the alkaline silicate produced by the action of the lime. The mass gradually becomes thoroughly indurated, and in a very short time is converted into a very compact stone, capable of sustaining extraordinary pressure, and increasing in strength and hardness with age.

The chemical actions which produce these results appear to be as below stated. When the before-named materials are mixed together, the alkaline silicate is immediately decomposed, the silicic acid combining with a portion of the lime present, forming a silicate of lime, whilst a portion of the alkali in a caustic condition is set free; this free alkali immediately seizes upon the natural soluble silica which constitutes one of the ingredients, and thus forms a fresh supply of silicate of soda, or potash, as the case may be, which is in its turn also decomposed by a fresh qaantity of lime ; and so on.

If each successive decomposition of the alkaline silicate resulted in setting free the whole of the alkali, these decomposing processes would continue so long as there remained any soluble silica present with which the alkali could combine, or until there ceased to be any free lime to decompose the silicate of soda or potash when produced; the termination of the action being marked by the presence in the stone of the excess of caustic alkali on the one hand, or of alkaline silicate on the other. In reality, however, the whole of the alkali does not appear to be set free as the soluble silicate is decomposed by the lime, there appearing to be formed a compound silicate of lime and soda (or potash), whereby a portion of the alkali becomes permanently fixed at each decomposition. The result of these several changes is that the whole of the alkali is gradually fixed, and none remains to be removed by any subsequent washing or other process.

The tenacious and enduring properties of silicate of lime are too well known to need any elaborate explanation in this paper. It is the substance which has conferred upon the old Roman mortars and concretes the enormous hardness they are found to possess even after a lapse of 2000 years and upwards.

Upon close examination of a piece of the old Roman concrete, we find that the hardest part of such concrete is not the lime with which it was combined, nor even the flint stones combined therewith, but the hard shelly film which has formed over the external surfaces of these stones, caused by the action of the lime with which they were in contact, and which is silicate of lime.

From the foregoing remarks it will be apparent that, in order to produce the most satisfactory results in the manufactory of artificial stone of the character of that now under consideration, special attention should be paid to the selection of suitable materials, and great care should also be observed in details of manipulation. The sand employed should be clean, sharp and silicious, free from argillaceous or cretaceous matter. The natural soluble silica exists, in large deposits, in various parts of the United States, and can be supplied in considerable quantities for manufacturing purposes, at a comparatively low price; but it must be borne in mind that these natural soluble silica deposits vary very considerably in the amount of their solubility; and, for the purpose of making the "Apœnite" stone, that which is most soluble in a given solution of caustic soda at a given temperature should be selected. Through the kindness of Dr. T. Sterry Hunt, of Boston, the author has received a sample of silicious earth, upwards of 90 per cent. of which is readily soluble, whereas several other samples from other localities have not furnished more than 40 per cent. under same conditions.

The silicate of soda also requires to be prepared with due regard to the proportions of silica and soda respectively, that containing 66 per cent. of silicic acid with 34 per cent. of soda being found in practice to produce the best general results. A sample of silicate of soda, furnished by Dr. Feuchtwanger, of New York, is now on the table, and appears to meet such conditions.

Very much also depends upon the selecton of the lime to be employed; and perhaps there are few articles of every-day consumption sold under the same name that differ more widely in their compositions and properties than limes and cements. These substances have been most thoroughly investigated, and the results published by Gen. Gilmore in his very useful "Practical Treatise on Limes, Hydraulic Cements and Mortars," and need only be alluded to in the present paper for the purpose of drawing attention to that which appears to be most suitable for the operations herein described. Amongst these may be selected that known as the hydraulic lime of Teil, and which derives its hydraulic energy from the large percentage of silicate of lime in its composition, viz., 66 per cent. It is slow in setting, thus affording time for proper manipulation in the process of stone-making, and attains high tensible strength, with great power to resist a crushing force. Its hydraulic properties have been largely tested in the construction of the marine works at Marseilles, Alexandria, and other seaports, as also in the great breakwater at the entrance to the Suez Canal and in the Mont Cenis Tunnel. Samples of this lime have been furnished to the author by Messrs. Champin & Gillet, of New York, who are the sole agents of the manufacturers for the supply of this lime in North America; there is also on the table a small fragment of concrete taken from the harbor works at Marseilles after having been submerged 23 years.

Well-burnt Portland cement, of good quality, may also be advantageously employed, instead of lime of Teil, where now immediate setting of the mass is required; but so many manufacturers of the so-called Portland cement have of late years sprung into existence in consequence of the increased demand for this article, and so much competition has been excited for the production of an hydraulic cement under this name at a low price, that more than ordinary care should be observed in its selection. The best Portland cement is composed of a mixture of white chalk and an alluvial deposit of rivers in a state of minute division, which substances, after being intimately incorporated mechanically, are burnt in a kiln to a point almost approaching vitrifaction, and afterwards ground and sifted, by which means a compound silicate of lime and alumina is formed, possessing the high hydraulic properties for which the Portland is so famed; but unless these ingredients be so mixed and burnt as to be chemically combined, instead of being merely mechanically incorporated, the so-called Portland cement may be worse than useless, and the employment of such material may lead to very disastrous results.

As comparatively few of the many persons who employ this material have any sufficient opportunity of personally ascertaining its essential properties, it is safer to rely upon the productions of such makers whose experience in the manufacture, and whose recognized standing in the commercial world form a sufficient guarantee for a genuine article.

Unquestionably there are such manufacturers upon the value of whose productions every reliance may be placed, amongst which, with many others, may be mentioned the names of Messrs. Vicat & Co. and Messrs. Lafarge, in France, and Messrs. White Brothers, the Burham Cement Co., and others in England, who have justly acquired a world-wide reputation. There may also possibly be makers of Portland cement of good quality in this country, but the author's experience has been far too limited to enable him to speak practically as to them.

Having explained the manufacture and chemical composition of the several descriptions of artificial stone herein alluded to, it will be as well in the next place to point out some of the varied purposes for which the "Apœnite" process is more especially applicable. The primary condition of materials for construction are, unquestionably, strength and durability, those of a secondary nature being appearance, facility of application to the intended purpose, and economy in use. As regards strength, it has before been stated that the stone manufactured by the "Apœnite" process increased with age. By some experiments which were made for the purpose of testing their possession of this quality, numerous samples were proved, within a month of their manufacture, to be superior to Portland stone. At the age of ten weeks the strength of "Apœnite," as compared with Portland stone, was found to be as 7145 lbs. to 2630 lbs. per square inch, and as compared with Bramly Fall, 7145 lbs. to 5120 lbs. per square inch. As regards durability, the well-known properties of the materials employed in its manufacture must serve as a sufficient guarantee upon this point until time should have offered corroborative and conclusive testimony.

In general appearance, the Ransome stone bears such a perfect resemblance to the natural sandstones as to mislead the most critical observers, whilst the facility of application and its economy in use will have been apparent from the foregoing description. By the last-mentioned process the field has been widely extended for the useful application of the "Apœnite" stone produced thereby. It is now no difficult task to produce blocks of this material of any form and of any size, the only limit being the means available for lifting them upon the spot where they are to be employed. Moreover, the greater part of the material required for its manufacture are, as a rule, generally to be found in abundance where hydraulic or other important works are being carried on, and for which purposes this new stone is eminently suited.

The want of such a material for such purposes has long been felt, although that want until recently has only been partially supplied. In the year 1870, Mr. Jas. W. Butler applied for and obtained a patent, in England, for improvement in the application of concrete to structures and foundations, and also to coffer-dams and similar constructions. Mr. Butler's obvious desire was in the first place to provide a cheap and efficient substitute for stone for hydraulic operations, and in the second to render unnecessary the construction of false works, etc., and thus to avoid the expense connected with the employment of iron cylinders, hitherto so extensively used. The idea was certainly an excellent one, but its practical realization appeared very remote until Mr. Butler's attention was directed to the new "Apœnite" stone, as a material necessary for the successful development of his proposed methods of construction. He accordingly communicated with the author upon the subject, and an opportunity was soon afforded for applying a practical test for the solution of this important question. Some extensive operations were at this time being carried out on the banks of the Thames in the construction of a retaining wall, to protect the fore shore at Hermitage wharf, under Mr. Butler's superintendence. Cast iron cylinders, 8 feet in diameter, were specified to be sunk, to form the face of the wall next the river, and the work had proceeded towards completion when, in consequence of the strike on the part of the workmen, and the sudden rise in the price of iron, considerable delay and difficulty was experienced in procuring the iron cylinders. In this dilemma Mr. Butler suggested to the engineer-in-chief (A. M. Rendel, Esq.), the employment of cylinders of "Apœnite" for the completion of the wall. The author was at once communicated with by that gentleman, and the order was given accordingly. The cylinders were 8 feet external diameter and 9 inches thick, made in lengths of about 4 feet each; when only a few days old they were sunk in the usual manner without any difficulty, and the result was so satisfactory to Mr. Rendel that in a letter he wrote to the author on the subject he expressed his regret that he could not have more of them. The arrangement proposed for economically carrying out this class of work is shown in the diagram. A timber staging is erected, upon which the materials may be mixed and moulded, the moulds consisting of an inner and outer framing, the space between the two forming the mould for each ring for a cylinder or hollow block, as the case may be; the courses are joined by means of a cement formed of similar material to that of which the rings or blocks are composed. These are lifted from the staging on which they have been made, and lowered into position by an over-head traveller or crane, as may be most convenient. The lowest course of the cylinder or hollow block is chamfered, as shown in the diagram, and when necessary, from the nature of the soil, may be shod with iron. The operation of sinking is carried out in a precisely similar manner to that adopted with iron cylinders. The horizontal joints are made with alternate projections and depressions, and the several courses are connected vertically by dowel piles, which also serve as guides in sinking the work. The application of this principle is capable of modification to suit almost every variety of construction, and it will be found especially applicable in structures requiring heavy foundations, particularly where the ground is uncertain or treacherous. For forming a face wall in building quays or docks, instead of cylinders, rectangular hollow blocks or caissons may be used. By employing hollow blocks of hexagonal form no interstices are left, a thin layer of the cementing material rendering the structure practically homogeneous.

Cylinders constructed upon this principle are also adapted for deep wells, apertures being formed in the sides for the admission of water. Turning to works of greater magnitude, it will be seen that "Apœnite" forms a peculiarly suitable substance for the construction of bridges, sea walls, piers and similar undertakings. In the case of piers for bridges the structure can be carried up to the underside of the bridge girders or built with ordinary masonry above high water level.

For sea walls or piers the arrangement shown in plan and section could be adopted. Here two rows of caissons are employed separately from each other longitudinally, the intermediate space being filled in with dry rubble hearting, and the blocks themselves with a similar material, or, if necessary, with concrete.

The author has recently inspected some works which are now in progress in this country, in which large blocks of Portland cement concrete are employed in the construction of the river wall. These concrete blocks, some of which are of the following dimensions, 14 ft. × 10 ft. × 5 ft. 6 in. = 77 cubic feet, weighing about 56 tons each, are moulded into form at a distance of upwards of two miles from the spot where they are finally to be deposited, and which, when sufficiently hardened, are transported by barges or floating derricks to their place of destination, where they are deposited in the ordinary mode of construction. If, in the place of these solid blocks of concrete, hollow blocks or caissons of "Apœnite" stone are constructed according to the design shown upon the accompanying plan, and after being placed in position were to be filled with good cement concrete, and backed with the same, the "Apœnite" blocks being firmly bonded together, as shown, and the concrete forming one entire mass throughout, the structure would be perfectly monolithic, and so thoroughly compacted together that it would be impossible to disturb the position of one part without exerting such a force as would be necessary to destroy the whole. In the accompanying sketch the dimensions of the proposed hollow blocks are shown as 24 ft. × 12 ft. × 6 ft., the "Apœnite" being 18 inches thick on the two sides, and 12 inches thick on the ends, each block being 6 feet high and measuring in external dimensions 1728 feet cube, of which 532 feet cube only will be composed of the "Apœnite" stone, and 1196 feet cube would be composed of the concrete filling. The "Apœnite" hollow blocks of the above dimensions, which would weigh about 40 tons each, may be made in any convenient place, and can be readily transported to the works where they are required to be permanently depasited, and will therein occupy more than three times the space of the present solid concrete blocks, whose cubical content is 30 per cent. greater.

In the case of an embankment for a reservoir, the heart of the bank, which is usually made with a puddle wall, is proposed to be substituted by two rows of "Apœnite" cylinders, the contained spaces being filled in with puddle, and the cylinders themselves with material similar to that of which the bank is made. This arrangement is also illustrated in the accompanying diagram. In sinking the cylinders they would be carried some distance below the natural surface, so as to obviate any chance of leakage below.

It is obvious that this plan could, without much difficulty, be applied to embankments already constructed where there was reason to apprehend that any settlement had occurred. By sinking the cylinders from the top through the puddle bank, but without removing any of the slope on either side, they would be carried down to sound ground, rendering the embankment safe, and removing all fear of danger in the future. A cheap and effective coffer-dam is also shown. Such a dam could be constructed under ordinary conditions, at a cost considerably below that of any other effective material. It would not be difficult to multiply instances in which this material can be practically employed; but enough has already been said on this point. An artificial stone combining the advantages of "Apœnite," one moreover which can be so readily moulded into any form or size with but small expense and little or no delay, and, moreover, one that is practically "fire-proof," is necessarily applicable to a great variety of uses. The author will therefore only briefly remark upon its applicability for ornamental and decorative purposes.

When prepared with suitable materials, the "Apœnite" is capable of receiving the most delicate impressions, and by the incorporation of the different metallic oxides, any variety of color can be imparted to it, so that artificial marbles or granites of almost every description can be produced. The artificial stones, like their originals, are capable of taking an excellent polish, are extremely hard, and can be readily moulded into the most elaborate forms, at a very small cost.

The author would only briefly allude to the testimony that has been borne to the value of the Apœnite process by engineers in England, whose names must be familiar to many of the present company, viz., Messrs. Hawksley, Hawkshaw, Bramwell, Vignoles, etc. When the author had the honor to read a paper on the subject before the mechanical section of the British Association last year, at which the President, at the close of the discussion which ensued, remarked, "I cannot refrain from saying that I believe the process of making artificial stone which Mr. Ransome has invented and perfected, is of very high importance indeed, that it has given to the world a new material which will be of great service, as well for the structural works of the engineer and architect as for purposes of ornamentation, and is eminently calculated to subserve many useful and important purposes in the industrial arts."

It now only remains for me to return my sincere thanks to you, sir, for affording me this opportunity of bringing my inventions under the notice of the members of this scientific institution, and to you, gentlemen, for the patience and courtesy you have extended to me in listening to the paper I have just had the honor of reading. I am aware that it contains many imperfections, which, however, I trust the subject of which it treats does not possess. but I must claim your indulgence, as it has been written in very great haste and without such materials at my command as I would have desired to enable me to illustrate the subject more fully. I, however, can only add that I shall be happy to supply any further information in my power verbally that may have been omitted from the body of the paper, and to answer any inquiries that may arise in the course of the discussion which I understand is now intended to follow.

DISCUSSION.

Mr. Henry Cartwright inquired of Mr. Ransome whether the artificial stone had ever been employed in the construction of piers for bridges or dock walls made in slabs set on edge, instead of in the cellular form, as shown in the diagrams.

Mr. R. replied that it had not been thus employed, as there would be some practical difficulty met with in that form, in securing the sides and ends of such blocks to retain the concrete filling.

The President.—In the manufacture of your Apœnite, is not the peculiar soluble silicious earth employed, that which is known as diatomaceous or infusorial earth ?

Mr. R.—The so-called infusorial earth is excellently suited for the purpose, though we have found very suitable materials which bear no evidence of infusorial origin. In this country such deposits are quite frequent. It is found abundantly near Richmond, in Virginia, in the neighborhood of Boston, and in several parts of California ; and doubtless, should the necessity for its use become generally appreciated, it could be detected in numerous other localities. I must beg here to express my obligations to many scientific men, whom I have met in this country, and who have greatly aided me by sending samples of such materials for my investigation or by referring me to new localities where they may be found.

Mr. JOHN SARTAIN asked whether it was applicable to the sculptural decoration of the exterior of buildings, and to all that class of artistic work in which terra-cotta is now extensively employed in continental Europe. For example, bas-relief panels or slabs of ornaments or groups, whether in low or high relief. The inquiry had special reference to the sculptural decoration of an important building to be devoted to art purposes, now in course of erection in Philadelphia.

Mr. RANSOME replied that it was; that it had been used not only for enriched copings over doors and windows, but also for capitals of corinthian columns, instanciug a new hospital building at London, erected on the river bank.

The PRESIDENT.—Does the Apœnite suffer any subsequent efflorescence?

Mr. R.—None at all. By the new process no washing is required, as is necessary with the "Ransome Stone." So long as sufficient soluble silica and lime are present in the materials, the whole of the soda is combined, and thus none is left free to effloresce. At each successive chemical action which occurs during the process of formation, a portion of the free soda becomes fixed. It is therefore only necessary to observe carefully the correct proportion of the several ingredients before mixing, in order to insure perfect freedom from this difficulty. I may mention also, incidentally, that the color of either of the stones may be varied at pleasure. By employing a light sand a light colored rock is obtained, with dark sand the reverse; or any color may be imitated by the employment of suitable metallic oxides. If, in connection with the foregoing, it is remembered that fragments of various degrees of coarseness may be employed with the sand, it will be perceived that the appearance of any of the natural stones may be closely imitated.

Mr. WM. V. MCKEAN.—I should like to be informed of some of the mechanical details of the manufacture of the stone.

Mr. R.—Mr. Ransome said that these were quite fully stated in the body of the paper.

Mr. ——— inquired whether the chloride of calcium process was still in use.

Mr. R.—Yes, quite largely, both abroad and in the United States. One good reason for its continuance, aside from the fact of the quality of the stone, is that the plant is there. The last process (apœnite) is, however, beyond question, the best.

Mr. ——— inquired how the stones stood the test of fire.

Mr. R.—Both the Ransome stone and the apœnite stand the fire well. They may be heated to redness without injury or material deterioration of their strength and hardness. The apœnite, however, seems to stand this test better than the other ; in fact, so well does it act in this particular that it would be quite practicable to make gas retorts of it.

Mr. ———. —What is the best material, with your process, for making the moulds for caps and columns ?

Mr. R.—Plaster of Paris is found generally most convenient. Where we have our choice, however, and the nature of the work permits of it, we use wood.

The PRESIDENT.—Are emery wheels made by the last process ?

Mr. R.—Yes ; very largely.

Mr. SELLERS.—When the "Ransome Stone" first began to be spoken of here, and the accounts of the method of working it were described in (I think) "Engineering," it seemed to me that the process might be utilized in forming emery wheels, which could be used either with water or oil. With this view we tried a number of experiments, and some wheels made by us on the Ransome plan were actually used in practice, but proved to have only a surface, wherein it is probable we did not get a perfect saturation of the chloride of calcium. We did, however, make some very pretty specimens of stone experimentally with various kinds of sand.

Mr. R.—The difficulty the President refers to was without doubt caused by the fact that, as the stone was made which he employed, the chloride of calcium was not made to penetrate into the interior, but simply affected the stone to a slight depth, while within, the same remained comparatively soft. Where the air-pump is employed, this material can readily be drawn through blocks of a foot or more in thickness, and this plan is invariably followed in the manufacture of this stone.

Mr. F. C. PRINDLE inquired if the stone was much used for drainage purposes.

Mr. R. replied that in the most instances bricks and similar materials were found to be cheaper.

Mr. F. C. PRINDLE.—What is the relative cost of the two kinds of stone?

Mr. R.—The cost of the apœnite will generally be about two-thirds that of the "Ransome Stone," but comparisons are difficult, inasmuch as this estimate will suffer many variations according to locality. Where the chloride of calcium can be obtained cheaply and in abundance, as in England, where it is a utilized waste product, the cost of the "Ransome Stone" will be moderated; while, on the other hand, the cost of the apœnite will depend largely upon the abundance and availability of suitable deposits of soluble silicious earth, &c.

Mr. PRINDLE.—Is it more possible to use coarse sand with the apœnite than with the other stone?

Mr. R.—Coarse sand may be used with both. Indeed we are often glad to use very coarse materials.

Mr. EDWARD TILGHMAN wished to know the difference between the so-called Victoria stone and those described by Mr. Ransome, or if the Victoria stone was not an invention of Mr. R's.

Mr. R.—I am happy to say that it is not the same. I am, however, fully acquainted with the history and process of the invention of the Victoria stone, since the inventor is a personal friend, and I was consulted before the application was made for the issue of a patent, because the claims upon some points might be construed to conflict with those of my own patents. The inventor uses sand in connection with Portland cement; broken granite, &c., is also employed. The mould with the plastic stone is then immersed in silicate of soda solution. Thus silicate of lime is formed at the surface of the block. I do not wish to be understood as disparaging in the least the value of this process, since most excellent results have been achieved by it.

At the close of the discussion Mr. Washington Jones moved that the thanks of the meeting be presented to Mr. Ransome for his most interesting and exhaustive paper. The motion was unanimously adopted.

Mr. Ransome, in acknowledging the vote of thanks, remarked that he had experienced so much kind attention from the members of the Institute, and such unexpected interest on their part in what he feared would prove uninteresting to them, that his thanks were due to them, rather than the reverse.

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